DOCUMENT RESUME

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IDENTIFIERS	Military Curriculum Project

ABSTRACT

These teacher and student materials, the second section of a two phase secondary/postsecondary-level course on aviation machinists, make up one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. The purpose of the course is to train students to maintain aircraft engines, perform intermediate and major inspections on engines and their related systems, field test and adjust components of engines, and replace compressor turbine blades and combustion chamber liners. This phase, Fixed Wing Aircraft, contains 7 weeks of instruction totaling 189 hours on: Reciprocating Engines (10 lessons, 27 hours); Fuels and Ignition (12 lessons, 27 hours); Starts, Stops, and Runups (4 lessons, 27 hours); and Troubleshooting (12 lessons, 27 hours). Instructor materials include a curriculum outline containing a weekly breakdown of lessons, topic objectives, equipment and furniture requirements, training aids and devices needed, and publications used as texts or references. The student materials consist of 10 chapters from the Navy training manual, "Aviation Machinist's Mate R 3 & 2, NAVPERS 10342-A." (YLB)

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MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL

Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
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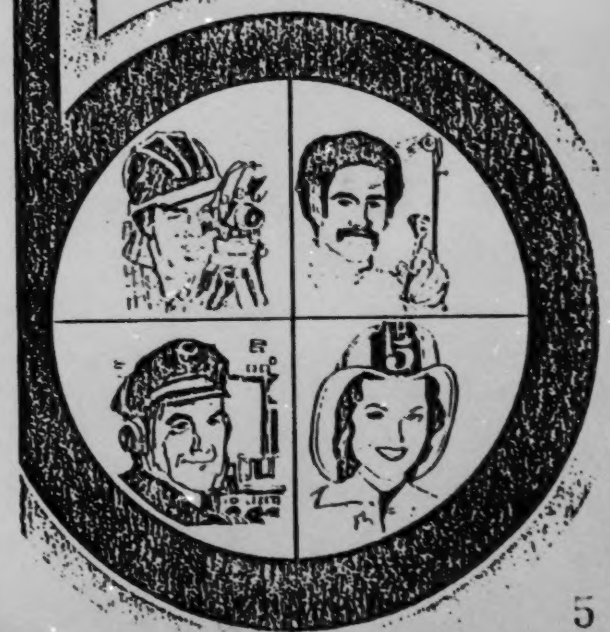
THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION

Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education



Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
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Springfield, IL 62777
217/782-0759

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AVIATION MACHINIST'S MATE, PHASE II

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Ground Handling Equipment and Procedures Page 223

Line Operations and Maintenance Page 236

AVIATION MACHINIST'S MATE, PHASE II

Classroom Course

2-6

Developed by:

United States Coast Guard

Development and Review Dates

March 19, 1975

D.O.T. No.:

639.281

Occupational Area:

Aviation

Target Audiences:

Grades 11-adult

Print Pages:

249

Cost:

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:	Type of Materials:						Instructional Design:				Type of Instruction:	
	Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Group Instruction:	Individualized:
Phase II — *Fixed Wing Aircraft*												
Reciprocating Engines (General)	●				●		●				●	
Fuels and Ignition	●				●		●				●	
Hydraulics	●				●		●				●	
Propellers	●				●		●				●	
Line Safety and Inspections	●				●		●				●	
Starts, Stops, and Run-Ups	●				●		●				●	
Troubleshooting	●				●		●				●	

THE CENTER FOR VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

Expires July 1, 1978

Course Description

This is the second section of a two-phase course for Aviation Machinists. Students completing the entire course will be able to maintain aircraft engines; perform intermediate and major inspections on engines and their related systems; field test and adjust components of engines including fuel pumps, valves, regulators, magnetos, and replace compressor turbine blades and combustion chamber liners. A third phase dealing with specific military aircraft was deleted. Students should complete **Aviation Machinist's Mate, Phase I** (2-5) before beginning this second phase of the course.

Phase II – **Fixed Wing Aircraft** contains seven "weeks" of instruction totaling 189 hours. Each "week" of instruction contains several lessons.

Week 7 – *Reciprocating Engines (General)* (ten lessons, 27 hours)
Week 8 – *Fuels and Ignition* (twelve lessons, 27 hours)
Week 9 – *Hydraulics* (twelve lessons, 27 hours)
Week 10 – *Propellers* (sixteen lessons, 27 hours)
Week 11 – *Line Safety and Inspections* (twelve lessons, 27 hours)
Week 12 – *Starts, Stops, and Runups* (four lessons, 27 hours)
Week 13 – *Troubleshooting* (twelve lessons, 27 hours)

This section of the two-phase course contains both teacher and student materials. Printed instructor materials include a curriculum outline containing a weekly breakdown of lessons, topic objectives, equipment and furniture requirements, training aids and devices needed, publications used as texts or references, and space requirements. The student materials consist of ten chapters from the Navy training manual, *Aviation Machinist's Mate R 3 & 2, NAVPERS 10342-A*.

Several additional military manuals and commercial texts were recommended for use as texts and references, but they are not provided. No specific audiovisuals were recommended. These materials can be adapted for individualized instruction or used as remedial or independent study in aircraft maintenance courses.

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[illegible]

3

CURRICULUM OUTLINE

FOR

CLASS "A" AD SCHOOL

A 21 WEEK COURSE

2-5 and
2-6

CLASSIFICATION: UNCLASSIFIED

PREPARED BY

USCG AIRCRAFT REPAIR AND SUPPLY CENTER

ELIZABETH CITY, N.C.

Reviewed By SME: G. J. ROY, CAPT, USCG
COMDT (G-EAE)

Approved By: P. E. [illegible]
Chief, Training and Education Division

19 MAR 1975

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5

1. **MISSION:** TO PROVIDE AVIATION MACHINIST'S MATE (AD) CANDIDATES WITH THE CLASS "A" LEVEL TRAINING NECESSARY TO FULFILL THE REQUIREMENTS FOR ADVANCEMENT TO AD3 AS SET FORTH IN THE CG-311, ENLISTED RATINGS QUALIFICATION MANUAL.

2. **SCOPE:** AVIATION MACHINIST'S MATES MAINTAIN AIRCRAFT ENGINES, TURBINE AND RECIPROCATING, AND THEIR RELATED SYSTEMS INCLUDING THE INDUCTION, COOLING, FUEL, OIL, COMPRESSION, COMBUSTION, TURBINE, IGNITION, PROPELLER AND EXHAUST SYSTEMS; PREFLIGHT AIRCRAFT; PERFORM INTERMEDIATE AND MAJOR INSPECTIONS ON ENGINES AND THEIR RELATED SYSTEMS; FIELD TEST AND ADJUST COMPONENTS OF ENGINES INCLUDING FUEL PUMPS, VALVES, REGULATORS, MAGNETOS AND OTHER COMPONENTS OF THE ENGINES AND ENGINE RELATED SYSTEMS; REMOVE, REPAIR AND REPLACE COMPRESSOR TURBINE BLADES AND COMBUSTION CHAMBER LINERS; MAINTAIN AND ADJUST HELICOPTER DRIVE SHAFTING, POWER TRANSMISSIONS, GEAR BOXES AND CLUTCH ASSEMBLIES; PRESERVE AND DEPRESERVE ENGINES, ENGINE ACCESSORIES AND COMPONENTS; AND SUPERVISE ENGINE SHOPS. PRACTICAL FACTORS FOR THE AVIATION MACHINIST'S MATE RATING ARE APPLICABLE TO THE AIRCRAFT AND EQUIPMENT ASSIGNED OR AVAILABLE.

3. **OBJECTIVES:**

   A. UPON COMPLETION OF THIS COURSE, THE TRAINEE WILL:

      (1) BE ABLE TO FULFILL THE TECHNICAL REQUIREMENTS FOR AVIATION MACHINIST'S MATE, THIRD CLASS, AS ESTABLISHED BY CG-311, ENLISTED RATINGS QUALIFICATIONS MANUAL.

      (2) HAVE DEMONSTRATED THE QUALITIES EXPECTED OF A COAST GUARD PETTY OFFICER.

   B. IN ORDER TO ACHIEVE THESE OBJECTIVES, THE TRAINEE MUST SATISFACTORILY COMPLETE THE CURRICULUM AS LISTED IN THE FOLLOWING PAGES, AND IN A MANNER CONSISTENT WITH AR&SC TRAINING DIVISION POLICIES.

b

Length of Course . . . . 21 Weeks . . . . 819 Hours

Based on a 39.0 hour week.

A training hour represents approximately sixty minutes of actual instruction. There are six such training hours in each day, with each separated by a ten minute break.

Military requirements are met by a fifteen minute period each morning prior to commencement of classes and one hour each Friday afternoon. This includes musters, marching, and classroom instruction.

BREAKDOWN OF TRAINING

1. Technical Training

    a. Classroom . . . . 409.0 Hours
    b. Line or practical . . . . 158.0 Hours

2. Supplementary Training

    a. Military. . . . . 52.5 Hours
    b. Physical. . . . . 31.5 Hours

3. Miscellaneous . . . . 168.0 Hours

AVERAGE WORK WEEK

1. Technical Training . . . . 27.0 Hours

2. Military Training . . . . 2.5 Hours

3. Physical Training . . . . 1.5 Hours

4. Miscellaneous . . . . 8.0 Hours

    a. Reviewing (Friday afternoon)

    b. Testing

    c. Cleanup

    d. Coffee Breaks

PHASE I (AIRMAN PREPARATORY)

Week 1 AD(A) School Indoctrination & Mathematics

	AD(A) School Indoctrination	4.0
1-1	Introduction to Mathematics	2.0
1-2	Fractions	3.0
1-3	Decimals	2.0
1-4	Percentages	2.0
1-5	Positive and Negative Numbers	1.0
1-6	Ratio and Proportion	2.0
1-7	Formulas	2.0
1-8	Angles	2.0
1-9	Triangles	2.0
1-10	Areas and Volumes	5.0
		27.0

Week 2 Physics

	Math Review	3.0
2-1	Matter and Electron Theory	2.0
2-2	Force and Pressure	2.0
2-3	Pascal's Law	2.0
2-4	Mechanics of Gases	4.0
2-5	Mechanics of Heat	4.0
2-6	Introduction to Diaphragm and Fluid Type Instruments	2.0
2-7	Force and Motion	2.0
2-8	Work and Power	2.0
2-9	Principles of Machines	2.0
2-10	Introduction to Gears	1.0
2-11	Introduction to Gyro Instruments	1.0
		27.0

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Basic Electricity

3-1	Introduction to Static Electricity	2.0
3-2	Introduction to Dynamic Electricity	2.0
3-3	Introduction to Ohm's Law and the Rheostat	2.0
3-4	Introduction to Series Circuits	3.0
3-5	Introduction to Parallel Circuits	3.0
3-6	Introduction to Magnetic Theory & Electromagnetism	3.0
3-7	Introduction to Electrical Components	4.0
3-8	Introduction to Safety Devices and Controls Voltage Regulators Reverse Current Relays Circuit Breakers	4.0
3-9	Introduction to Basic Aircraft Electrical Systems	3.0
3-10	The Simpson Multimeter	1.0
		27.0

Week 4 Aerodynamics/Weight & Balance/Instruments

4-1	Introduction to Aircraft	6.0
4-2	Fundamental Rotation and Stresses	2.5
4-3	Aircraft Controls & Systems	3.5
4-4	Atmospheric Effects on Aircraft	1.5
4-5	Introduction to Aerodynamics	4.5
4-6	Rotary Wing Aerodynamics	3.0
4-7	Introduction to Weight & Balance	6.0
		27.0

Week 5 Hardware & Handtools

5-1	Introduction to Hardware & Materials	4.0
5-2	Introduction to Common Handtools	6.5
5-3	Nuts, Bolts, Screws, Fasteners and Special Aircraft Hardware	6.5
5-4	Saftey Devices & Safety Wiring Practical	10.0
		27.0

Week 6 Publications

6-1	Introduction to the Naval Aeronautical Publication Index, 01, 02 and 03 Series of Publications	4.0
6-2	Introduction to the Federal Supply System	4.0
6-3	Bulletins and Changes (Navy)	1.0
6-4	CG ATN, ATO, AMB, and AMC's	1.0
6-5	CG Directives, Publications, and Reports Index - CG-236	1.0
6-6	Flight Record Form CG-4377	1.5
6-7	UR Form, CG-4010	1.0
6-8	Aircraft Records	6.0
6-9	Aircraft Material Stocking List, CG-298	1.5
6-10	Introduction to Air Force Technical Order System	3.0
6-11	Introduction to Coast Guard Technical Order System	1.0
	Practical	2.0
		27.0

PHASE II (Fixed Wing Aircraft)

Week 7 Reciprocating Engines (General)

7-1	Introduction to Power Plants	2.0
7-2	Radial Engine Breakdown	1.0
7-3	Principals of Engine Operation	4.0
7-4	Cylinders, Valves, and Valve Operating Mech.	3.0

Week 7 Reciprocating Engines (Continued)

7-5	Power Transmission Mechanisms	2.0
7-6	Superchargers	2.0
7-7	Cooling and Exhaust System	1.0
7-8	Introduction to Lubrication System	2.0
7-9	Introduction to Aviation Lubricants	2.0
7-10	Introduction to Carburetion	8.0
		27.0

Week 8 Fuels & Ignition

8-1	Aviation Fuels	1.5
8-2	Introduction to Aviation Fluids	1.0
8-3	Introduction to Aircraft Fuel Systems	1.5
8-4	Fuel - Air Ratios	.5
8-5	Introduction to Reciprocating Engine Ignition Sys.	1.0
8-6	Types of Magnetos	1.0
8-7	Circuits & Components of the S9LU Mag.	2.0
8-8	Mechanical Operation of the S9LU Mag.	1.0
8-9	Electrical Operation of the S9LU Mag.	2.0
8-10	Description & Operation of the Induction Vib.	1.0
8-11	Introduction to Spark Plugs	1.0
8-12	Timing the S9LU Magneto (Practical)	13.5
		27.0

Week 9 Hydraulics

9-1	Basic Principle and Theory of Hydraulics	3.0
9-2	Operation of a Basic Aircraft Hydraulics System	.5
9-3	Hydraulic Sealing Devices and Hydraulic Fluids	1.0
9-4	HU-16E Hydraulic System (General)	3.0

Week 9 Hydraulics (Continued)

9-5	HU-16E Main Hydraulic System	5.0
9-6	HU-16E Sub. System	5.0
9-7	HU-16E Hand Pump System	3.0
9-8	Shock Struts	1.0
9-9	The Nose Wheel Shimmy Damper	1.0
9-10	The Variable Delivery Pump	3.0
9-11	The Independent Brake Master Cylinder	.5
9-12	The Disc Type Brake	1.0
		27.0

Week 10 Propellers

10-1	Introduction to Propeller Theory & Types	4.0
10-2	Introduction to the 43D50 Prop.	1.0
10-3	Introduction to the 43D50 Prop. Blade Assy.	1.0
10-4	Introduction to the 43D50 Hub Assy.	1.0
10-5	Introduction to the 43D50 Oil Trans. Housing Assy.	1.0
10-6	Introduction to the 43D50 Prop. Dome Assy.	2.0
10-7	Introduction to the Low Pitch Stop Lever Assy.	1.0
10-8	Introduction to the Control Slip Ring Assy. Including the Brush Pad Bracket Assy.	1.0
10-9	Introduction to the Double-Acting Gov. Assy.	1.0
10-10	Introduction to the StepMotor Electric Head Assy.	2.0
10-11	Introduction to the Integral Oil Control Pump Housing	3.0
10-12	Introduction to the Aux. Oil Supply System	1.0
10-13	Introduction to the Prop Electrical Circuit	2.0
10-14	Procedures for Propeller Servicing	1.0
10-15	Introduction to the 43D50 Prop Deicing System	1.0
10-16	Prop. Removal & Installation (Practical)	4.0
		27.0

Week 11 Line Safety & Inspections

11-1	Introduction to Tow Vehicles	1.0
11-2	Introduction to Mobile Elect. Power Plants	2.0
11-3	High & Low Pressure Air, Uses & Characteristics	.5
11-4	Safety in Maintenance	2.0
11-5	Line Safety	2.0
11-6	Introduction to Maintenance Stands & Equipment	.5
11-7	Aircraft Servicing & Ground Handling	2.0
11-8	Introduction to Periodic Inspection	2.0
11-9	Introduction to the HU-16E Work Card System	1.5
11-10	Introduction to Phased Inspection	1.0
11-11	Introduction to Aircraft Corrosion	2.0
11-12	Periodic Inspection, Practical Application	10.5
		27.0

Week 12 Starts, Stops, & Runups

12-1	Aux. Power Plant	2.0
12-2	Introduction to Start & Stop the HU-16E Engine	2.0
12-3	Operational Runup of HU16E	4.5
12-4	Practical Application	18.5
		27.0

Week 13 Troubleshooting

13-1	Introduction to Trouble Shooting	1.0
13-2	Universal Prop. Protractor	.5
13-3	Introduction to the Dial Indicator	.5
13-4	Introduction to the Piston Position Indicator (Time Rite)	1.0
13-5	Introduction to the Magneto Timing Light	1.0
13-6	Introduction to the Cold Cylinder Indicator	1.0
13-7	Introduction to the S-1 Type Diff. Comp. Tester	1.0

Week 13 Trouble Shooting (Continued)

13-8	Introduction to the High Volt. Insulation Tester	1.0
13-9	Trouble Shooting Aircraft Systems	1.0
13-10	Trouble Shooting the R-1820-76 Engine	3.0
13-11	Line Maintenance of HU-16 Engine	1.5
13-12	Practical Application	14.5
		27.0

PHASE III (Rotary Wing Aircraft)

Week 14 Intro to the HH52A Helicopter

14-1	Development & Theory of Rotary Wing Flight	3.0
14-2	HH52A Airframe	2.0
14-3	HH52A Electrical System	4.0
14-4	HH52A Fuel System	4.0
14-5	HH52A Gear Boxes and Drive Shafts	5.0
14-6	HH52A Rotor Head and Blades	6.0
14-7	HH52A Flight Control Systems	3.0
		27.0

Week 15 Intro to the HH52A Helicopter (Continued)

15-1	HH52A Hydraulic System	6.5
15-2	HH52A Landing Gear System	6.5
15-3	HH52A Heater System	3.0
15-4	HH52A Hoist System	2.0
15-5	HH52A Fire Detector & Extinguishing Systems	2.5
15-6	Review of Torquing Procedures, Safety Wiring and Hardware & Publications	6.5
		27.0

Week 16 Intro to the T-58 Engine

16-1	Jet Engine Theory	4.0
16-2	T-58 Engine	2.0
16-3	Compressor & Accessory Section of the T-58 Engine	3.0

Week 16 Intro to the T-58 Engine

	Combustion Section of the T-58 Engine	1.0
16-5	Gas Generator Section of the T-58 Engine	2.0
16-6	Power Turbine Section of the T-58 Engine	1.0
16-7	Airflow of the T-58 Engine	2.0
16-8	Lubrication System of the T-58 Engine	2.0
16-9	Fuel System of the T-58 Engine	6.0
16-10	Electrical and Stator Vane Actuating Systems of the T-58 Engine	3.0
16-11	Introduction to HH52 Corrosion Control	1.0
		27.0

Week 17 Intro to the T-58 Engine Practical

17-1	Jet Engine Preservation	2.0
17-2	T-58 Engine Removal	1.0
17-3	Preparation of the T-58 Engine for Shipment	1.0
17-4	Removal of the T-58 Engine from the Shipping Container	1.0
17-5	T-58 Engine Inspection Procedures	2.0
17-6	T-58 Engine Accessory Removal	6.0
17-7	T-58 Engine Power Turbine Removal	14.0
17-8	T-58 Engine Gas Generator Turbine Removal	- -
17-9	T-58 Engine Combustion Section Removal and Compressor Section Splitting	
		27.0

Week 18 T-58 Practical (Continued)

18-1	Installation of Compressor Stator & Combustion Section	5.0
18-2	Installation of Gas Generator & Power Turbine Sections	5.0
18-3	Installation of Accessories, Lines, Leads, and Fittings	6.0
18-4	Installation of T-58 Ready Engine Kit Components	5.0
18-5	Introduction to Removal of the HH52A Main Rotor Head Assy.	1.0
18-6	Removal of Rotor Head & Main Transmission of the HH52A	5.0
		27.0

Week 19 HH52A Practical

19-1	Maintenance of the HH52A Main Rotor Head & Gearbox Assemblies (2 Hours Class, 10 Hours Practical)	12.0
19-2	Installation of the Main Rotor Head & Star Assembly	3.0
19-3	Installation of Main Gear Box Quick Change Unit Practical	12.0
		27.0

Week 20 HH52A Line Servicing & Maintenance

20-1	Engine Installation & Depreservation Engine Installation Practical	1.5 5.5
20-2	Preflight & Servicing Requirements for the HH52A Preflight Practical	2.0 4.0
20-3	Rescue Hoist & Platform Recovery Procedures Rescue Hoist Operational Check Out Aircraft Hoisting Exercise (Live Hoisting Under Supervision)	2.0 2.0 3.0
20-4	Aircraft Ground Handling Aircraft Ground Handling Practical	1.5 2.0
20-5	Aircraft Taxi Signals Aircraft Taxi Signals Practical	1.0 2.5
		27.0

PHASE I (AIRMAN PREPARATORY CONTINUED)

Week 21 Military - CG-333 - Survival

21-1	Introduction to USCG Warrant Officer Specialties & Uniform Identification	1.0
21-2	Air Station Organization	2.5
21-3	Introduction to Air Station Watch Lists	1.5
21-4	Introduction to Shipboard Armament	.5
21-5	NBC Warfare	1.5
21-6	Survival	4.0
21-7	Survival Equipment Practical	8.0 2.0
21-8	Flight Physiology & Water Survival Training Practical (Conducted at Navy Norfolk on a facility available basis)	3.0 3.0
		27.0

16

WEEK 1

TITLE

Introduction to Mathematics

TOPIC OBJECTIVE

To familiarize the student with general mathematics, fractions, decimals, percentages, positive and negative numbers, ratio and proportion, introduction to angles, area's and volumes, and triangles. The student will be able to:

(a) Name and explain the mathematical terms used.

(b) Correctly solve problems utilizing the terms and formulas discussed.

WEEK 2

TITLE

Introduction to physics

TOPIC OBJECTIVE

To familiarize the student with matter, electron theory, force and pressure, Pascal's Law, heat, force and motion, work and power, principles of machines, and gears. The student will be able to:

(a) Define the physics terms discussed in this week.

(b) List and explain the laws dealing with physics.

(c) Solve problems working with formulas used in physics.

WEEK 3

TITLE

Introduction to Basic Electricity

TOPIC OBJECTIVE

To introduce the student to the theory of basic electricity, electrical components, safety devices, basic DC aircraft electrical systems and the Simpson Multimeter. The student will be able to:

(a) Define and explain the following:

    (1) Static Electricity.
    (2) Dynamic Electricity.
    (3) Ohm's Law and the Rheostat.
    (4) Series Circuit.
    (5) Parallel Circuits.
    (6) Magnetic Theory and Electromagnetism.
    (7) Electrical Components.
    (8) Safety Devices and Controls.
    (9) Basic DC Aircraft Electrical System.
    (10) Simpson Multimeter.

(b) Describe safety precautions to be observed when dealing with electricity and electrical components.

(c) Solve electrical problems utilizing the Ohm's Law formula.

(d) Explain current flow and resistance.

WEEK 4

TITLE

Introduction to Aerodynamics

TOPIC OBJECTIVE

To familiarize the student with types and classes of aircraft, rotational axis and stresses encountered in flight, aircraft control systems, atmospheric effects on aircraft, aerodynamics, rotary wing aerodynamics, weight and balance, electrical and remote reading instruments, and navigation instruments. The student will be able to:

(a) Explain safety precautions outlined in CG ATN-4-71 to be observed when maintenance is performed on an aircraft control system.

(b) Define the terms, laws, and principles utilized in aerodynamics.

(c) Solve problems in weight and balance utilizing the terms, formulas and load adjuster.

Describe the purpose of electrical and navigation instruments.

WEEK 5

TITLE

Hardware and Handtools

TOPIC OBJECTIVE

To familiarize the student with the selection and proper use of the more common hardware and handtools associated with aviation, including certain special tools, ie. micrometers, torque wrenches etc. Also introduces him to the correct safety procedures associated with hardware and handtools. The student will be able to:

(a) List and explain properties of metals, metal characteristics, forms, shapes and alloys utilized.

(b) List the two types of tubing used in aircraft, explain the color coding used to identify tubine systems and list and explain installation procedures and precautions.

(c) Identify, describe and list uses of selected common handtools including Vernier Micrometers and dial indicators.

Identify, describe and list uses of the more common hardware including control cables, turnbuckles, control rods, and rod ends. Describe the use of a tensiometer.

(e) Identify, explain uses of, and safety precautions involved with different safety wire and cotter pins. Satisfactorly demonstrate his knowledge and ability by completing a sample safety wire and cotter pin board in one hours time.

WEEK 6

TITLE

Publications

TOPIC OBJECTIVE

To familiarize the student with the various forms, publications, logs and records associated with Coast Guard Aviation. The student will be able to:

(a) Name the five parts and describe the purpose of the Naval Aeronautical Publications Index. Explain the Navy publications numbering system. Explain the difference between a manual and a letter type publication. Describe the purpose of the maintenance manual and the illustrated parts breakdown. Explain the sequence of events for locating a manual or letter type publication.

(b) Name and describe the three parts of a federal stock number. Identify by name the CRL1N, CRL2N, and NMDL. Explain the sequence of events for determining the FSN, unit of issue, description, and price of an item beginning with a part number.

(c) Name and explain the purpose of and the three catagories of changes and bulletins (Navy).

(d) Name and explain the purpose of AMB's, AMC's, ATN's and ATO's.

(e) Name and describe the purpose of the directives, Publications and Reports Index, CG-236. Describe the security classification system, its purpose and identifing code, and the method of numbering and filing directives.

(f) Identify by number the aircraft flight record form, CG-4377 and explain the purpose of each part, and the method of numbering and filing the aircraft flight record.

(g) Identify by number and explain the purpose, importance, and the desired results of the unsatisfactory report form, CG-4010.

(h) Name, describe, and explain the purpose of the aircraft log and record.

(i) Identify and explain the purpose of OPNAV 4790/35, Maintenance Instruction.

(j) Identify and explain the objectives of the aircraft material stocking list. List and describe the three categories of material as listed therein.

WEEK 6 (Cont'd)

(k) Name and explain NI&RT and list of applicable publication systems. Describe the AFTO system and its purpose. Explain the AFTO numbering system.

(l) Describe the Coast Guard technical order system and its purpose.

WEEK 7

TITLE

Reciprocating Engines (General)

TOPIC OBJECTIVE

To familiarize the student with various types of reciprocating engines, engine construction, engine components and engine operation. The student will be able to:

(a) Explain the purpose of the cooling and exhaust systems.

(b) Name and describe various components used in a basic lubrication system.

(c) List the components in sequence of oil flow through a dry sump system.

(d) Explain the classification system of Aviation lubricants and the importance of proper handling and storage.

(e) Describe the units, the designation of and operation of the pressure carburetor.

WEEK 8

Title

Fuels and Ignition

Topic Objective

To familiarize the student with basic requirements of aviation fuels, octane rating and performance numbers; how they are established and identified, and safety precautions to be observed while handling. The student will be able to:

(a) Explain the requirements of a basic aircraft fuel system and functions of various components that comprise a basic aircraft fuel system.

(b) Explain the path of fuel flow on the HU-16E, the importance of fuel air ratios and their effects on engine operation, to indentify by name various indications of improper fuel air mixtures.

(c) State the purpose of an engine ignition system and list the major components which make up an engine ignition system, state their purpose and location on the engine or aircraft, define terms applicable to aircraft magnetos and interpret each character of the designation S9LU-3.

(d) List the three (3) circuits of the S9LU-3 and describe their purpose and construction features.

(e) Describe the mechanical operation of magnetos, draw the complete magnetic and electrical circuits of the S9LU-3 and explain current flow.

(f) Describe the types of spark plugs used in Coast Guard aircraft; how they are constructed and precautions to be used while handling.

(g) Demonstrate the ability to bench time the S9LU-3, and time a magneto to an R-1820 engine in the time alloted.

WEEK 9

Title

Hydraulics

Topic Objective

To familiarize the student with a basic understanding of a hydraulic system including components, types of fluid, operation and minor maintenance. At the completion of this week the student will be able to:

(a) Name and describe the advantages and disadvantages of a hydraulic system.

(b) Name and describe the essential components in a practical hydraulic system (hydraulic jack), and explain how force is transmitted from input to output.

(c) Solve correctly simple mathematical problems illustrating the mechanical advantage achieved in hydraulics.

(d) Explain the purpose of each component in a basic hydraulic system.

(e) Name and describe the various sealing devices used in aircraft hydraulic systems.

(f) Explain the application and purpose of the different design hydraulic sealing devices.

(g) Name and describe the types of hydraulic fluids and their characteristics.

(h) Name and describe the types of hydraulic systems used in the HU-16E.

(i) Name and describe the components that are common to both power operated systems.

(j) List the pressure limits and volumes of the components that are common to both power operated systems.

(k) Perform minor maintenance on the system.

WEEK 10

Title

Propellers

Topic Objective

To familiarize the student with basic propeller types, propeller theory, operation, removal, installation, servicing and safety. The student will be able to:

(a) Explain the forces created by a rotating propeller, how the propeller produces thrust, and safety rules to be observed in the area of propeller rotational plane.

(b) Explain the meaning of various letters and numbers in the propeller hub assembly model designation and identify the seven (7) components that make up the 43D50 propeller.

(c) List and describe the major parts of the propeller hub assembly; state the location, purpose and the flow of oil through the hub. explain the proper procedure for securing and locking the hub assembly to the propeller shaft.

(d) List and describe the major parts of the propeller blade and state the location of each. Explain the purpose of each major part of the assembly.

(e) List and describe the purpose, major parts, location and functions of the dome assembly.

(f) State the location and purpose of the slip ring and brush pad and how they are mounted.

(g) State the location, purpose and operation of the governor stepmotor head and integral oil system.

(h) State the purpose of the aux oil system. List and describe the components and operation of the aux oil system.

(i) List and describe the major components of the propeller electrical circuit and explain its operation.

(j) List the proper oil acceptable for use in the 43D50 propeller and correct procedures for servicing.

(k) Name and identify components of the deicing system and explain its operation.

(l) Explain the proper procedure for removal and installation of the 43D50 propeller assembly.

WEEK 11

Title

Line Safety and Inspections

Topic Objective

To familiarize the student with general ground support equipment, operating procedures and safety precautions. The student will be introduced to:

(a) General ground support equipment, including demonstrations.

(b) Aircraft servicing and ground handling.

(c) Inspection methods and procedures.

(d) Aircraft corrosion and corrosion control practices.

(e) HU-16E periodic inspections.

WEEK 12

Title

Starts, Stops and Run-ups

Topic Objective

To familiarize the student with the correct procedures for inspection and operation of the APU and the R1820 Engine. The student will be able to:

(a) Demonstrate the purpose, application and use of the V-32D-2 APU.

(b) Perform pre-flight and post-flight inspections of the HU-16E aircraft.

(c) Perform starts, run-ups and stops of the APU and Main engines of the HU-16E, in compliance with the NATOPS Manual 01-85-AC1 and the Standardization Manual, CG-372.

WEEK 13

Title

Trouble Shooting

Topic Objective

To familiarize the student with the correct methods, tools and procedures for effective trouble shooting and minor discrepancy repairs. The student will be able to:

(a) Explain the reason for trouble shooting, where to locate information concerning the trouble and the use of the four step and V.I.C.E. method used in trouble shooting.

(b) Demonstrate the ability to correctly use and the purpose of the following items:

universal propeller protractor
dial indicator
piston position indicator
magneto timing light
cold cylinder indicator
S-1 type differential compression tester
high voltage tester

(c) Demonstrate the ability to make idle mixture and idle speed adjustments; fuel and oil adjustments; remove, inspect and install spark plugs; clean reciprocating engines.

MODIFICATIONS

Pages 24-29 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

APPENDICES

SECTION A EQUIPMENT AND FURNITURE REQUIREMENTS PAGE A1

SECTION B TRAINING AIDS AND DEVICES PAGE B1 THRU B2

SECTION C PUBLICATIONS USED AS TEXTS OR REFERENCES PAGE C1 THRU C6

SECTION D SPACE REQUIREMENTS PAGE D1

SECTION E STAFFING REQUIREMENT BY GRADE AND RATE WITH ORGANIZATION PAGE E1 THRU E3

Number of an item	
1	Hanger air compressors, ingersol rand
1	Bandsaw, do-all
65	Bookcase, section, metal
17	Bookcase, base, metal
6	Buffer, floor
1	Cabinet, duplicator
7	Cabinet, file, metal, letter size
25	Cabinet, storage
1	Calculator, Victor 1800
1	Calculator, Friden
23	Chairs, swivel, desk
159	Chairs, student
1	Chalk & bulletin board
1	Charger, battery
1	Cleaner, steam
8	Coat racks
1	Floor Jack
1	Cutter, Paper
7	Desk, metal, double pedestal
13	Desk, metal, single, pedestal
3	Drill, electric, hand
1	Drill, Pneumatic, hand
1	Drill press
6	Fan, pedestal
1	S-16E Cabinet, 8 X 5 card
2	Grinder, bench
1	Lathe, metal turning
13	Lockers, metal single
1	Machine, duplicating, ditto
1	Reel, air hose
1	Sander, belt & disc
1	Saw, electric circular
1	Saw, recipricating
1	Saw, miter box
1	Refrigerator
1	Sander, orbital
1	Saw, horizontal band
8	Stand, office machine
4	Stools, draftsman
114	Table, student
2	Tap & die set
4	Typewriter, office, Electric
1	Vacuum cleaner
2	Water cooler
1	Welder, electric, 1 ea Burner/welder oxy/acetylene
2	Couches (Student lounge)
4	Lounge chairs (Student Lounge)

TRAINING AIDES AND DEVICES

Number of each item	
2	HU16E Aircraft
3	HH52A Helicopter (1 operational)
1	Applicator, Water
1	Applicator, rust lick
1	Auxiliary Power Unit
2	Borescopes
5	Chalk Boards
8	Carts, 3 Shelves with castors
2	Compression Tester
1	Copy maker, Thermal image
1	Compressor, air, Cornelius
1	Electronic Stensil Cutter
1	Gantry, 3 Ton Capacity
350	16mm movies
1	Hydraulic Power Unit
1	Grease Gun, Lincoln Pneumatic
1	Hoist, electric
1	Indicator, dial
3	Jack, AC 3 Ton
1	Jet Cal. Tester
1	Kit, T58, special tools
3	Multimeters
1	Micrometer, set
1	Micrometer, depth
1	Power supply,+ Portable, 28 VDC
1	Preservation unit, engine
2	Projector, opaque
5	Projector, 16mm
1	Projector, Sound on Slide
7	Projector, overhead
6	Protractor, propellop
1	Puller Kit, mechanical, bearing/bushing
1	Rectifier, 28 VDC
2	Screen, slide & movie, portable
1	S.V.A. Ind, Kit T58
1	Tester, Delta P
1	Tester, Torque Wrench
1	Tool Box, Roll Around
1	Tractor, Towing
1	Vacublast machine
6	Vise, bench
8	Wrench, torque
2	T58 engines
2	1820 QEC's
1	HU16E Hydraulic system mock-up
1	HU16E Fuel System mock-up

1	HU16E Propeller system mock-up
1	HU16E Propeller cut away
3	HH52A Maintenance stands
2	Universal tow bars
1	HU16E Heater system mock-up
1	HH52A Heater system mock-up
1	HU16E Electrical system mock-up
1	HH52A Electrical System mock-up
1	HU16E Engine instruement system mock-up
1	HU16E Auto Pilot system mock-up
1	HU16E Fuel Indication system mock-up
1	Radial engine ignition siming & valve mock-up
3	T-58 Engine carts
1	T-58 Engine cans
1	1820 Engine cut-away
1	HH52A Transmission & rotor head cut-away
3	HH52A Rotor blades & stand
2	HU16E Oil Tank cut-away
1	43D50 Propeller & Stand
1	Propeller bench
1	Hydraulic testing unit
ALL	43D50 Propeller special tools
ALL	T-58 Engine special tools
ALL	HH52A special tools
2	T-58 Engine nose stands
2	T-58 Engine power turbin stands
1	Waukeshaw portable power unit
2	Aero stands
4	HU16E Maintenance stands
ALL	1820 special tools

PUBLICATIONS USED AS TEXTS OR REFERENCES

WEEK 1 - A. Math Study Guide CNATT-P-630
B. Basic Mathematics, Vol. 1

WEEK 2 - A. Aviation Physics Study Guide and Workbook, CNATT-P-40
B. Powerplants for Aerospace Vehicles, CH-10, page 200-201 (Third Edition)
C. Basic Electricity, NAVPERS 10086A
D. Airman Manual NAVPERS 10307A
E. Aviation Electricians Mate 3&2 NAVPERS 10348-B
F. The New American Machinist's Handbook, by Rupert Legrand

WEEK 3 - A. Basic Electricity, NAVPERS 10086A
B. Aviation Physics Workbook CNATT-P-40
C. USCG pamphlet no. 210
D. AE 3&2 Manual NAVPERS 10348-B
E. Powerplants for Aerospace Vehicles

WEEK 4 - A. NIT Basic Science, chapter 8 (Third Edition)
B. BUWEPS INST 13100.7
C. Airman Manual NAVPERS 10307A
D. CG ATN 4-71
E. Sikorsky Theory of Flight
F. Helicopter History and Aerodynamics Manual NAVAIR 00-80T-88
G. DD form 365 A, B, C, & F
H. Aviation Electricians Mate 3&2 NAVPERS 10348-B

WEEK 5 - A. FAA Airframe and Powerplant Mechanics Manual (AC65-15)
B. Airman Manual NAVPERS 10307
C. AMS 3&2 NAVAER 10308
D. NIT Basic Science Aerospace Vehicles (Third Edition)
E. Military Standards MS 33540

WEEK 6 - A. Maintenance Instructions Manual NAVWEPS 01-85AB-2
B. Illustrated Parts Breakdown NAVWEPS 01-85AB-4
C. CRL1N, CRL2N, NMDL, C0006
D. ATN 5-60
E. CG-199-1, CG-236
F. Commandant Instruction 13090.2A
G. ATN 5-70
H. Commandant Instruction 13090.1A
I. OPNAVINST 4790.2, Vol. II
J. CG-298 A/C Material Stocking List
K. AFTO 00-5-1, 00-5-2, NI&RT 0-1-01

PUBLICATIONS USED AS TEXTS OR REFERENCES

WEEK - 7 A. NAVPERS #10343A
B. FAA Powerplant Manual AC65-12
C. NIT Powerplants for Aerospace Vehicles
D. NAVPERS #10342A
E. NAVWEPS #00-80T-42
F. NAVAIR 02A-35GH-502
G. HMI R1820-76 Engine
H. NAVWEPS 03-108A-101 PD12K-10 Carb Manual

WEEK - 8 A. Powerplants for Aerospace vehicles 3rd Ed Nit
B. NAVPERS 10342
C. Aviation fuels NAVAER 06-5-501
D. NAVAIR 01-85AB-2 HU16-E E&M Manual
E. NAVPERS 10335A
F. FAA Airframe and Powerplants Manual AC65-12 CH.4
G. COMDT INST 13000 series, GREB3B
H. Time-rite piston position instruction book
I. NAVAIR 02A-35GH-502

WEEK - 9 A. NAVPERS # 10310A
B. Basic science for Aerospace Vehicles
C. NAVWEPS 01-85AC-1, NW01-85AB-2

WEEK -10 A. Powerplants for Aerospace Vehicles 3rd ED. N.I.T.
B. Hamilton Standard's Prop to Pilot
C. NW 03-20CC-38
D. NW 03-20CC-39
E. NW 03-20CC-40
F. NA 01-85AB-2

WEEK -11 A. NAVPERS 10342-A (ADR 3&2)
B. NAVAIR 19-45-10
C. NAVPERS 10307-C (AIRMAN)
D. USCG Institute course for AD2
E. NAVWEPS 00-80T-96
F. NAVPERS 1037-B
G. NA 01-85AB-2
H. NA01-85AC-1
I. ATN 1-71 & 1-71D
J. Maintenance & repair of aero space
K. Vehicles N.I.T.
L. HU16 Aircraft Model Bulletin 145
M. ATN 4-71
N. NA 01-1A-509
O. ATN 1-68

WEEK -12 A. NA 01-AC-1
B. NA 01-AB-2
C. NA 01-85AC-1

PUBLICATIONS USED AS TEXTS OR REFERENCES

D. NA 01-85AB-2
E. CG 372
F. NA 02A-35GH-502

WEEK -13 A. NAVAIR 01-85AB-2
B. NAVWEPS 10085-A
C. NAVAIR 02A-35GH-502
D. CG 372
E. NAVWEPS 01-1A-506

WEEK -14 A. NW 00-80T-88
B. Sikorsky Theory of Flight
C. CGTO 1H-52A-1
D. CGTO 1H-52A-2
E. Sikorsky Service School Manual

WEEK -15 A. CGTO 1H-52A-1, HH52A Flight Handbook
B. CGTO 1H-52A-2, HH52A Maintenance Manual
C. CGTO 1H-52A-4, HH52A I.P.B.
D. NA 02B-105AHB-2

WEEK -16 A. Powerplants for Aerospace vehicles 3rd ED (NIT)
B. Jet Aircraft Power Systems 3rd ED (NIT)
C. T-58 Engine Training Guide
D. NA 02B-105AHB-2
E. T58-G#-88 Intermediate Maintenance Manual

WEEK -17 A. NA02B-105AHB-2
B. NA 15-02-500
C. CGTO 1H-52A-2
D. CGTO 1H-52A-6
E. CGTO T58-8B-6EM Series work cards
F. CGTO 1H-52A-6FI work cards
G. ATN 1-71

WEEK -18 A. CGTO T58-8B-6EM
B. NA 02B-105AHB-2
C. CGTO 1H-52A-2

WEEK -19 A. CGTO 1H-52A-2

WEEK -20 A. CGTO 1H-52A-2
B. NA 0213-105AH13-2
C. CGTO 1H-52A-6
D. ATN NO. 1-71
E. HH52A Bulletin No. 40
F. CGTO 1H-52A-1
G. NAVPERS 10307-B

WEEK -21 A. USCG Pamphlet No. 159
B. Coast Guardsman Manual
C. CG 333
D. CG 294
E. CG Pahphlet No. 108, 109

PUBLICATIONS USED AS TEXTS OR REFERENCES

F. NAVWEPS 00-80T-56, NAVAIR 13-1-6.2
G. NAVPERS 10087, NAVAIR 00-80-T-52
H. CG Pamphlet No. 458

SPACE REQUIREMENTS

Office Spaces	Space Required
Chief, AD Training Branch Office	151 sq ft
Asst Chief, AD Training Branch Office	144 sq ft
Testing and Files Office	300 sq ft
Instructors Offices	1475 sq ft
Conference Room	475 sq ft
Student Lounge	448 sq ft
Classrooms for AD(A) School-3 each with minimum of	475 sq ft
HU-16E (C) School Classroom	1000 sq ft
HH-52A (C) School Classroom	875 sq ft
T-58 Engine and Propeller Shop	2000 sq ft
Shop (Training Aids Maintenance)	616 sq ft
Training Aids Storage	744 sq ft
Special Tool Storage	250 sq ft
Store Room	150 sq ft
Head, Student's and Staff	322 sq ft
Furnace Room	112 sq ft
Total Floor Space including Hangar	25,690 sq ft

MODIFICATIONS

Section E of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

Aviation Machinist's Mate R3&2
NAVPERS 10342-A
41

CHAPTER 5

2-6

TOOLS AND HARDWARE

TOOLS

The ADR3 and ADR2 must have a well rounded knowledge of many different types of tools and the purpose for which they are designed. One of the most important attributes that a mechanic can have is the ability to use the tools that he will need for the everyday performance of his job, whether it be a simple and minor adjustment of a component or a major job such as an engine change.

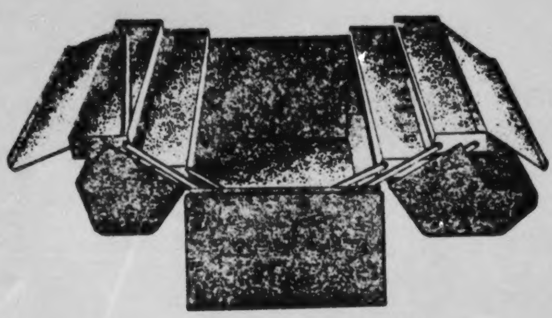
A mechanic is known by the tools he keeps. The use of tools may vary, but safety, good care, and the proper stowage of tools never vary. Some of the various tools (including selection, use, and care) that the ADR might use in the performance of his duties are described in the following paragraphs.

NOTE: Two Rate Training Manuals—Basic Handtools, NavPers 10085-A, and Airman, NavPers 10307-B—also contain a description of most tools used by the ADR, together with detailed instructions for using them. The material covered in this chapter is intended to supplement, rather than repeat, the information given in these training manuals and should be studied in conjunction with them.

HANDTOOLS

When an ADR reports to an activity, it is highly probable that he will be issued a toolbox or toolkit. The size of the toolbox or toolkit will depend on the work center to which he is assigned. It could be a small toolkit issued to plane captains, a medium sized toolbox for troubleshooters, or the standard Navy toolbox used by most powerplant check crews. (See fig. 5-1.)

The toolbox will most likely contain only those tools needed often in performing the assigned tasks. The tools should be organized in the box by type and size, and those needed often placed where they can be reached without digging through the entire contents of the box. Tools should be maintained in an orderly fashion, and extras such as aircraft parts, pieces of "junk," etc., kept out of the box.



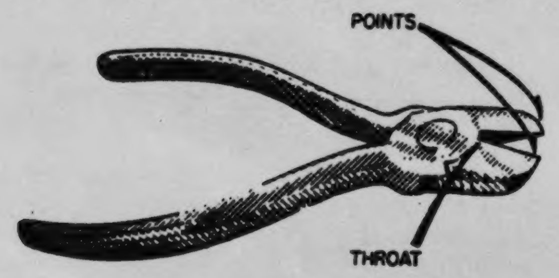
AM.14

Figure 5-1.—Standard Navy toolbox.

Diagonal Pliers

Diagonal cutting pliers (fig. 5-2) are used for cutting small, light material, such as wire and cotter pins in areas which are inaccessible to the larger cutting tools.

As the cutting edges are diagonally offset approximately 15 degrees, diagonal pliers are adapted to cutting small objects flush with a surface. The inner jaw surface is a diagonal straight cutting edge. Diagonal pliers are damaged easily and should not be used in place of tin snips or other metal cutting tools designed for heavier work. Diagonal pliers should never be used to hold objects, because they exert a greater shearing force than other types of


POINTS
THROAT

AM.15

Figure 5-2–Diagonal cutting pliers.

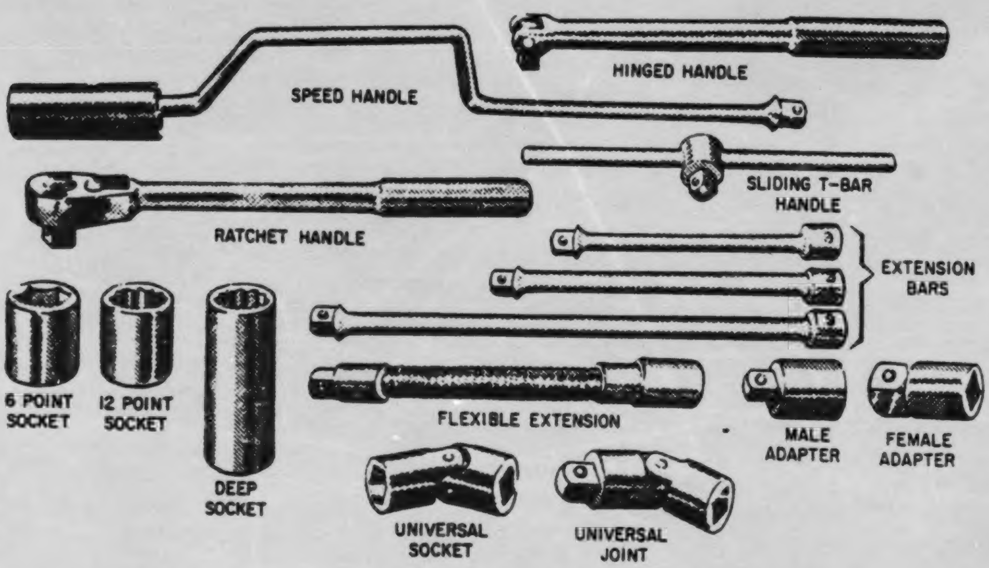
pliers of a similar size. The sizes of the diagonal cutting pliers are designated by the overall length of the pliers.

Socket Wrench

The socket wrench is one of the most versatile wrenches in the toolbox. Basically, it consists of a handle and a socket type wrench which can be attached to that handle. A complete socket wrench set consists of several types of handles along with bar extensions, universals, adapters, and a variety of sockets. (See fig. 5-3.)

SOCKETS.–A socket has an opening cut in one end to fit a drive on a detachable handle. The handle drive is usually square. In the other end of the socket is a 6-point or 12-point opening very much like the opening in the box end wrench. The 12-point socket needs to be swung only half as far as the 6-point socket before it has to be lifted and fitted on the nut for a new grip. It can therefore be used in closer quarters where there is less room to move the handle. Most sockets have 12-points. However, the 6-point socket has its use with nuts made of stainless steel, which are made of harder metal than that of the wrench. Extensive use of a 12-point socket on such nuts or bolts would cause excessive wear on the 12-points so that the socket might fail to hold. By contrast, because of the greater holding surface, a 6-point socket holds the stainless steel nut better, offering less chance for wear of the wrench.

Sockets are classified for size according to two factors. One is the drive size or square opening which fits on the square drive of the handle. The other is the size of the opening in the opposite end, which fits the nut or bolt. The standard aircraft mechanic toolbox is usually outfitted with sockets having 1/4-, 3/8-, and 1/2-inch-square drives. The openings that fit onto the bolt or nut are graduated in 1/16-


SPEED HANDLE
HINGED HANDLE
SLIDING T-BAR HANDLE
RATCHET HANDLE
EXTENSION BARS
6 POINT SOCKET
12 POINT SOCKET
DEEP SOCKET
FLEXIBLE EXTENSION
MALE ADAPTER
FEMALE ADAPTER
UNIVERSAL SOCKET
UNIVERSAL JOINT

AM.18

Figure 5-3.–Typical socket wrench set.

inch sizes. Sockets are also made in deep lengths to fit over spark plugs and long bolt ends.

There are four types of handles used with these sockets. (See fig. 5-3.) Each type has special advantages, and the good mechanic chooses the one best suited to the job at hand. The square driving lug on the socket wrench handles has a spring-loaded ball that fits into a recess in the socket receptacle and holds the assembly together. This mated ball-recess feature prevents the parts of the wrench from falling apart during normal usage, but a slight pull disassembles any wrench connection.

RATCHET HANDLE.–This handle has a reversing lever which operates a pawl (or dog) inside the head of the tool. Pulling the handle in one direction causes the pawl to engage in the ratchet teeth and to turn the socket. Moving in the opposite direction causes the pawl to slide over the teeth, permitting the handle to back up without moving the socket. This allows rapid turning of the nut or bolt after each partial turn of the handle. With the reversing lever in one position, the handle can be used for tightening. In the other position, it can be used for loosening.

HINGED HANDLE.–The hinged handle is also very convenient. To loosen a tight nut, swing the handle at right angles to the socket. This gives the greatest possible leverage. After loosening the nut to the point where it turns easily, move the handle into the vertical position and then turn the handle with the fingers.

SLIDING T-BAR HANDLE.–While using the sliding bar on T-handle, the head can be positioned at either the end or the center of the sliding bar. Select the position which is needed for the job at hand.

SPEED HANDLE.–The speed handle is worked like the woodworker's brace. After the nuts are first loosened with the sliding bar handle or the ratchet handle, the speed handle will help remove the nuts in a hurry. In many instances the speed handle is not strong enough to be used for breaking loose or tightening. The speed socket wrench should be used carefully, to avoid damaging the nut threads.

ACCESSORIES.–To complete the socket wrench set, there are several accessory items. Extension bars of different lengths are made to extend the handles to any length needed. A universal joint allows the nut to be turned with the wrench handle at an angle. A universal socket is also available; and universal socket joints, bar extensions, and universal sockets in combination with appropriate handles make it possible to form a variety of tools that will reach otherwise inaccessible nuts and bolts.

Another accessory item which comes in handy sometimes is an adapter which allows the ADR to use a handle having one size of drive with a socket having a different size of drive. For example, a 3/8- by 1/4-inch adapter would make it possible to turn all 1/4-inch-square drive sockets with any 3/8-inch square drive handle.

There are special sockets which are used to adapt various types of screwdriver bits to a speed handle (fig. 5-4). This socket type screwdriver is used to remove recessed head screws from access panels on aircraft.

Combination Wrench

The ADR's toolbox should contain a complete set of combination wrenches. The combination wrench (fig. 5-5) has an open-end wrench on one end and a box-end (of the same size) on the other end. For speed and light stress operations, use the open-end; then switch to the box-end for safety under stress. For ease of explanation, each end of the wrench will be discussed separately.

The box-end fits completely around the nut or bolthead. The box-end is usually constructed

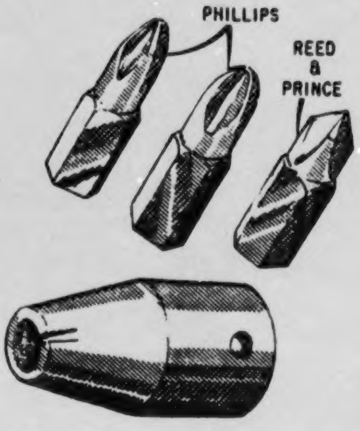


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Figure 5-4.–Screwdriver adapter.

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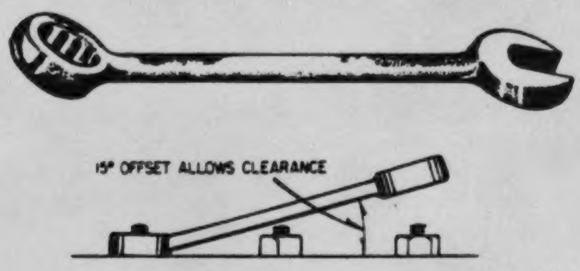

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Figure 5-5.–Combination wrench.

with 12 points. The advantage of the 12-point construction is that the wrench will operate between obstructions where space for the handle to swing is limited. A very short swing of the handle will turn the nut far enought to allow the wrench to be lifted and the next set of points to be fitted to the corners of the nut. It is possible to use this wrench in places where the swing angle is limited to as little as 30 degrees.

The box-end portion of the wrench is designed with an offset in the handle. Notice in figure 5-5 how the 15 degrees offset will allow clearance over nearby parts. One of the best features of the box-end is that there is little or no chance of a wrench slipping off the nut or bolt. However, there is the disadvantage of slow work with the box-end of the combination wrench. Each time the wrench is backed off, the wrench has to be lifted up and refitted to the head of the work. Therefore, to save time, use the nonslip box-end of the wrench to break loose tight bolts or to snug up work after the bolt has been seated with a faster type wrench which might slip under stress.

The jaws of the open end portion of the combination wrench are machined at 15 degrees from parallel in respect to the centerline of the handle. This permits the use of the wrench in places where there is room to make only a part of a complete turn of a nut or bolt. If the wrench is turned over after the first swing, it will fit on the same flats and turn the nut farther. After two swings on the wrench, the nut is turned far enough so that a new set of flats are in position for the wrench.

The open end of the combination wrench may be used on tubing nuts and in cramped places too small for a socket or box-end to be slipped over the nut or bolthead. When using any open end type wrench, always insure that the wrench fits the nut or bolthead, and pull on the wrench–never push. Pushing a wrench is dangerous. The threads could break loose unexpectedly and cause damage to adjacent equipment or injury to the person using the wrench.

Adjustable Wrenches

Adjustable wrenches are not intended to replace open end wrenches, but they are useful in working in restricted areas. In addition, they can be adjusted to fit odd size nuts. However, adjustable wrenches are not intended for standard use but rather for emergency use. They were not built for use on extremely hard-to-turn items. As shown in figure 5-6, adjustable wrenches have a fixed jaw (A) and an adjustable jaw (B) which is adjusted by a thumbscrew (C). By turning the thumbscrew, the jaw opening may be adjusted to fit various sizes of nuts. The size of the wrenches ranges from 4 to 18 inches. The maximum jaw openings vary in direct proportion to the length of the handle.

Adjustable wrenches are often called "knuckle busters" because mechanics frequently suffer the consequences of improper usage of these tools.

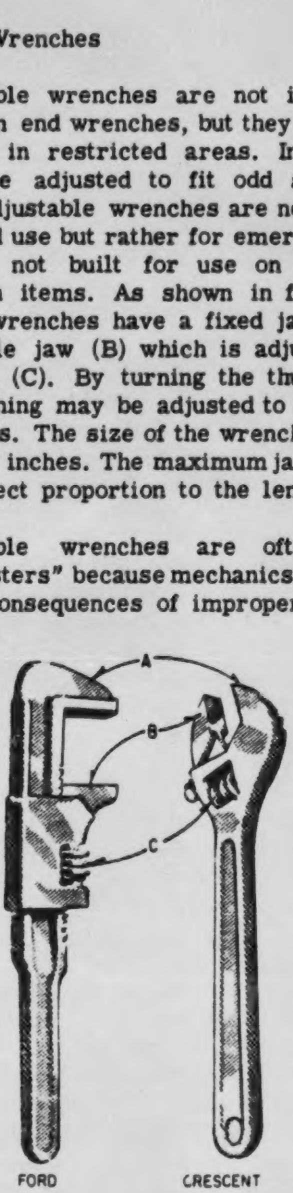

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Figure 5-6.–Adjustable wrenches.

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There are four simple steps to follow in using these wrenches. First, choose one of the correct size; that is, do not pick a large 12-inch wrench and adjust the jaw for use on a 3/8-inch nut. This could result in a broken bolt and a bloody hand. Second, be sure the jaws of the correct size wrench are adjusted to fit snugly on the nut. Third, position the wrench around the nut until the nut is all the way into the throat of the jaws. If not used in this manner, the result is apt to be as bloody as before. Fourth, pull the handle toward the side having the adjustable jaw. This will prevent the adjustable jaw from springing open and slipping off the nut. If the location of the work will not allow all four steps to be followed when using an adjustable wrench, then select another type of wrench for the job.

Adjustable wrenches should be cleaned in a solvent, and a light oil applied to the thumbscrew and the sides of the adjustable jaw. They should also be inspected often for cracks which might result in failure of the wrench.

Screwdrivers

Two basic screwdriver blade types are used—the common blade for use on conventional slotted screws and a crosspoint blade for use on the recessed head Phillips or Reed and Prince type screws. Both types of screwdrivers are illustrated in figure 5-7. The common and crosspoint blade types are used in the design of various special screwdrivers, some of which are also shown in figure 5-7.

COMMON SCREWDRIVERS.—The combined length of the shank and blade identifies the size of common screwdrivers. They vary from 2 1/2 to 12 inches. The diameter of the shank and the width and thickness of the blade tip which fits the screw slot are in proportion to the length of the shank. The blade is hardened to prevent it from being damaged when it is used on screws. It can easily be chipped or blunted when used for other purposes. The blade of a poor quality screwdriver will sometimes become damaged even when being used properly.

A damaged common screwdriver may be repaired by dressing the blade if done correctly. This can be done by the following instructions:

1. Dress the sides with an emery wheel so that the blade is symmetrical in shape.

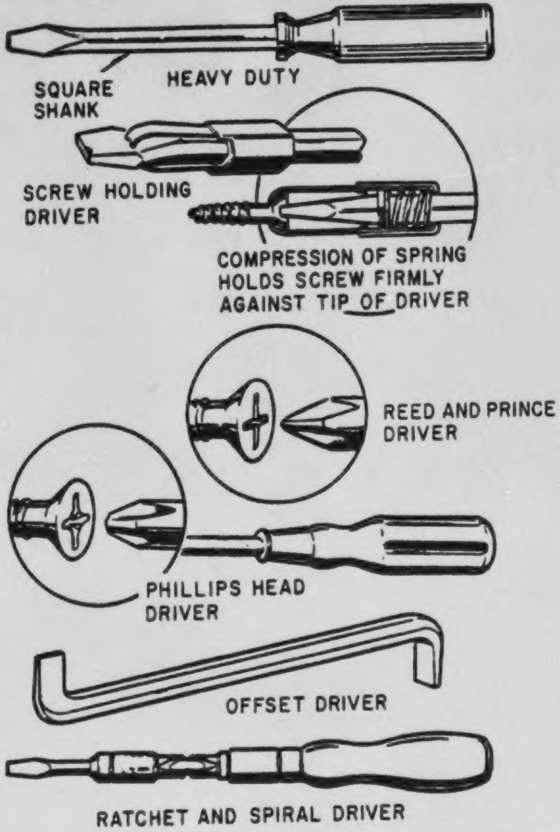

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Figure 5-7.—Typical screwdrivers.

2. Square off the end with the wheel; check for squareness by resting the tip on the handle of a trysquare, and move the shank of the screwdriver close to the blade of the trysquare. If the blade of the trysquare and shank are parallel, the tip is square.

CROSSPOINT SCREWDRIVERS.—There are two types of crosspoint screwdrivers in common use—the Reed and Prince, and the Phillips. The Reed and Prince screwdrivers and Phillips screwdrivers are NOT interchangeable; therefore, always use a Reed and Prince screwdriver with Reed and Prince screws and a Phillips screwdriver with Phillips screws. The use of the wrong screwdriver will result in mutilation of the screwhead.

OFFSET SCREWDRIVERS.—An offset screwdriver (fig. 5-7) may be used where there is not sufficient vertical space for a standard screwdriver. Offset screwdrivers are constructed with one blade forged in line and another blade forged at right angles to the shank handle. Both blades are bent 90 degrees to the shank handle. By alternating ends, most screws can be seated or loosened even when the swinging space is very restricted. Offset screwdrivers are made for both standard and recessed head screws.

CAUTION: When using any type of screwdriver, do not hold the work in the hand. If the point slips, it can cause a bad cut. The ADR will always be safe when following this rule: Never get any part of the body in front of the screwdriver point. This is a good safety rule for any sharp-pointed tool. When removing a screw from an assembly that is not stationary, hold the work on a solid surface, in a vise, or with some other holding tool.

Hammers

Generally speaking, this group is composed of various types of hammers, all of which are used to apply a striking force where the force of the hand alone is insufficient. Each of these hammers is composed of a head and a handle, even though these parts differ greatly from hammer to hammer. So that the ADR may have a better idea of their differences and uses, let's consider the types of hammers used most frequently. (See fig. 5-8.)

BALL-PEEN HAMMER.–The ball-peen hammer is sometimes referred to as a machinist's hammer. It is a hard faced hammer made of forged tool steel.

The flat end of the head is called the face. This end is used for most hammering jobs. The other end of the hammer is called the peen. The peen end is smaller in diameter than the face and is therefore useful for striking areas that are too small for the face to enter.

Ball-peen hammers are made in different weights, usually 4, 6, 8, and 12 ounces and 1, 1 1/2, and 2 pounds. For most work, a 1 1/2-pound and a 12-ounce hammer will suffice.

MALLETS.–A mallet is a soft faced hammer. Mallets are constructed with heads made of brass, lead, tightly rolled strips of rawhide, and plastic or plastic with a lead core for added weight.

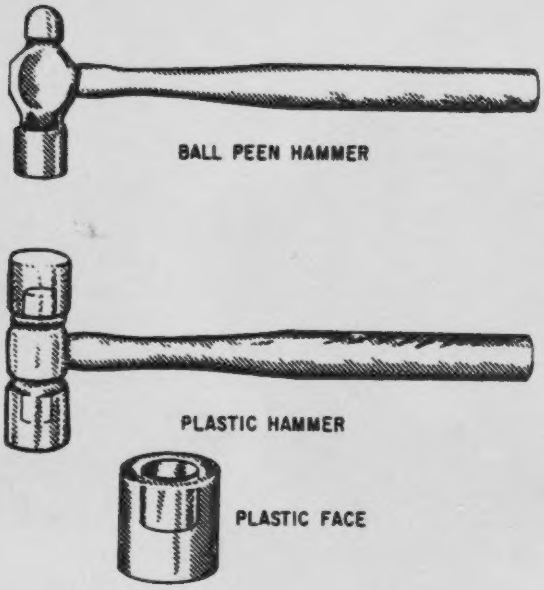

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Figure 5-8.–Hammers.

Plastic mallets similar to the one shown in figure 5-8 are the type normally found in the ADR's toolbox. The weight of the plastic head may range from a few ounces to a few pounds. The plastic mallet may be used for straightening thin sheet ducting or when installing clamps.

SAFETY PRECAUTIONS.–Hammers are dangerous tools when used carelessly and without consideration. Practice will help the ADR to learn to use a hammer properly. Some important things to remember when using a hammer or mallet are as follows:

Hold the handle near the end with the fingers underneath and the thumb along the side or on top of the handle. The thumb should rest on the handle and never overlap the fingers. Oil on the face of the hammer will cause it to glance off the work; therefore, wipe the oil off with a rag then rub the face with coarse sandpaper or emery cloth. Never use a hammer which has a loose head or cracked handle. It is dangerous to personnel and to property. Most hammer accidents are caused by a loose head or a slippery handle, so remember this when using any kind of striking tool. Tighten the loose hammerhead by driving a wedge in the end of the handle. This spreads the handle tightly inside the head. Do not strike a hardened steel surface with a steel hammer. Small pieces of steel may break and injure someone or damage the work. Use a soft hammer in striking hardened steel or highly polished stock. If a soft hammer is not available, use a piece of copper, brass, lead, or wood to protect the hardened steel. However, it is permissible to strike a punch or chisel directly with the ball-peen hammer because the steel in the heads of punches and chisels is slightly softer than that of the hammerhead.

Vise Grip Pliers

The ADR uses this tool a number of ways. These pliers can be adjusted to various jaw openings by turning the knurled adjusting screw at the end of the handle. Vise grips can be clamped and locked in position by pulling the lever toward the handle. The vise grip pliers are shown in figure 5-9. They may be used as a clamp, speed wrench, portable vise, and for many other uses where a locking, plier type jaw may be employed.

CAUTION: Vice grip pliers should be used with care since the teeth in the jaws tend to damage the object on which they are clamped. They should not be used on nuts, bolts, tube fittings, or other objects which must be reused.

Channel-Lock Pliers

Channel-lock pliers (fig. 5-10) can be easily identified by the extra-long handles, which make them a very powerful gripping tool. The inner surfaces of the jaws consist of a series of coarse teeth formed by deep grooves, a surface adapted to grasping cylindrical objects. Channel locks have grooves on one jaw and lands on the other. The adjustment is effected by changing the position of the grooves and lands. The channel locks are less likely to slip from the adjustment setting when gripping an object. The channel-lock pliers will only be used where it is impossible to use a more adapted wrench or holding device. Many nuts and bolts and surrounding parts have been damaged by improper use of channel-lock pliers.

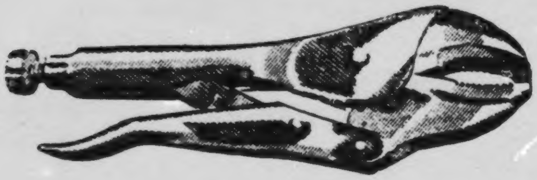

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Figure 5-9.–Vise grip pliers.

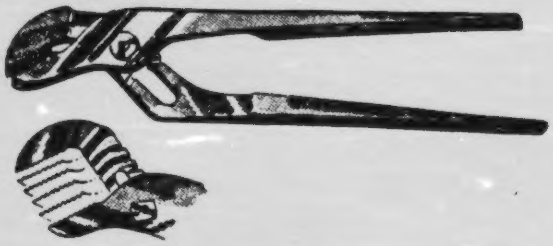

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Figure 5-10.–Channel-lock pliers.

Duckbill Pliers

Duckbill pliers (A, fig. 5-11) have long wide jaws and slender handles. Duckbills are used in confined areas where the fingers cannot be used. The jaw faces of the pliers are scored to aid in holding an item securely. Duckbills are ideal for twisting the safety wire used in securing bolts, nuts, and screws.

Needle-Nose Pliers

Needle-nose pliers (B, fig. 5-11) are used in the same manner as duckbill pliers. However, there is a difference in the design of the jaws. Needle-nose jaws are tapered to a point which makes them adapted to installing and removing small cotter pins. They have serrations at the nose end and a side cutter near the throat. Needle-nose pliers may be used to hold small items steady, to cut and bend safety wire, or to do numerous other jobs which are too intricate or too difficult to be done by hand alone.

NOTE: Duckbill and needle-nose pliers are especially delicate. Care should be exercised when using these pliers to prevent springing, breaking, or chipping the jaws. Once these pliers are damaged, they are practically useless.

Wire-Twister Pliers

Wire-twister pliers (C, fig. 5-11) are three-way pliers, which hold, twist, and cut. They are

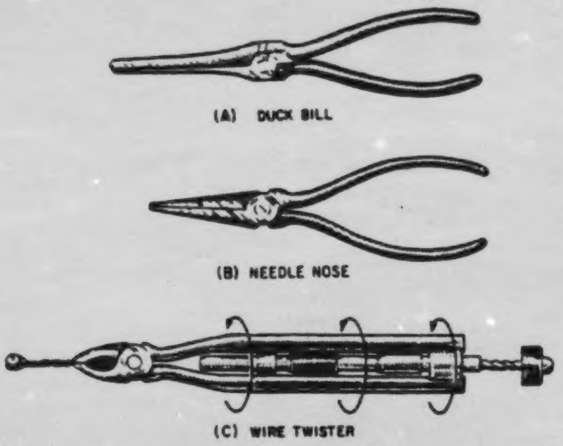

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Figure 5-11.–Pliers. (A) Duckbill; (B) needle nose; and (C) wire twister.

designed to reduce the time used in twisting safety wire on nuts and bolts. To operate, grasp the wire between the two diagonal jaws, and the thumb will bring the locking sleeve into place. A pull on the knob twirls the twister, making uniform twists in the wire. The spiral rod may be pushed back into the twister without unlocking it, and another pull on the knob will give a tighter twist to the wire. A squeeze on the handle unlocks the twister, and the wire can be cut to the desired length with the side cutter. The spiral of the twister should be lubricated occasionally.

Mechanical Fingers

Small articles which have fallen into places where they cannot be reached by hand may be retrieved with the mechanical fingers. This tool is also used when starting nuts or bolts in difficult areas. The mechanical fingers, shown in figure 5-12, have a tube containing flat springs which extend from the end of the tube to form clawlike fingers, much like the screw holder. The springs are attached to a rod that extends from the outer end of the tube. A plate is attached to the end of the tube, and a similar plate to be pressed by the thumb is attached to the end of the rod. A coil spring placed around the rod between the two plates holds them apart and retracts the fingers into the tube. With the bottom plate grasped between the fingers and enough thumb pressure applied to the top plate to compress the spring, the tool fingers extend from the tube in a grasping position. When the thumb pressure is released, the tool fingers retract into the tube as far as the object they hold will allow. Thus, enough pressure is applied on the object to hold it securely. Some mechanical fingers have a flexible end on the tube to permit their use in close quarters or around obstructions.

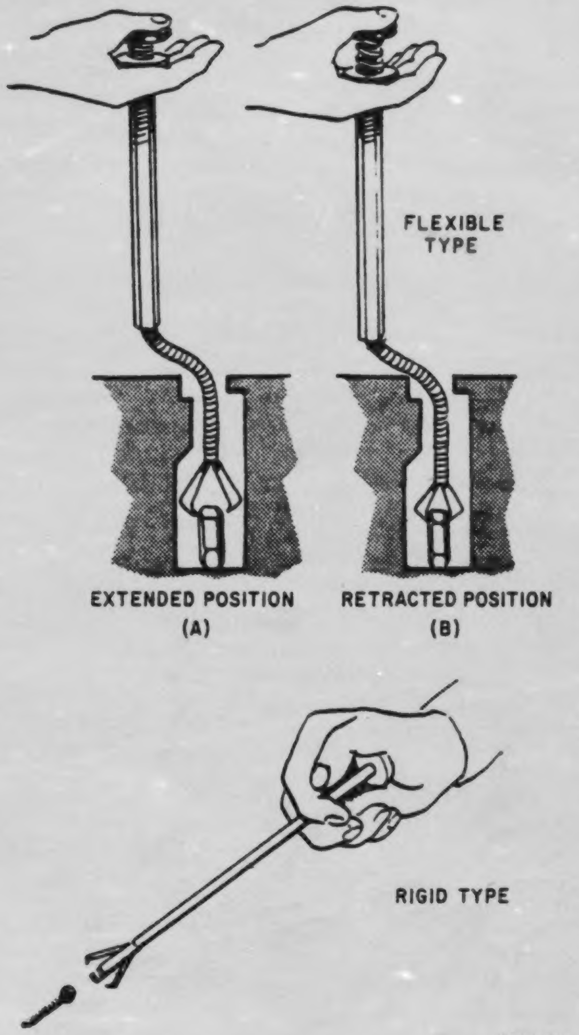

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Figure 5-12.–Mechanical fingers.

NOTE: Mechanical fingers should not be used as a substitute for wrenches or pliers. The fingers are made of thin sheet metal and can be easily damaged by overloading.

Flashlight

Each toolbox should have a standard Navy vaporproof two-cell flashlight. The flashlight is used constantly during all phases of maintenance. Installed in both ends of the flashlight are rubber seals which keep out all vapors. The flashlight should be inspected periodically for the installation of these seals, the spare bulb, and colored filters which are contained in the end cap. NOTE: Do not throw away the filters; they will be necessary during night operations, especially carrier operations.

Inspection Mirror

There are several types of inspection mirrors available for use in aircraft maintenance. The mirror is issued in a variety of sizes and may be round or rectangular. The mirror is connected to the end of a rod and may be fixed or adjustable. (See fig. 5-13.)

The inspection mirror aids in making detailed inspection where the human eye cannot directly see the inspection area. By angling the mirror, and with the aid of a flashlight, it is possible to inspect most required areas.

Selection, Use, and Care

In the selection of handtools always use the proper tool for the job. Never use wrenches or pliers as hammers, screwdrivers for pry bars, etc. Never use makeshift tools or tools that are not in good repair. A tool that is broken or in poor condition is the surest way to ruin the equipment to be repaired. Although the ADR will be assigned to a particular work center, his work area could be numerous places such as the line, high power turnup area, hangar deck, flight deck, etc. Therefore, the proper selection, use, and care of handtools could mean a considerable savings in manhours and materials. The selection and use of the right tools are the mark of a good mechanic.

The care of handtools should follow the same pattern as for personal articles; that is, always keep handtools clean and free from dirt, grease, and foreign matter. After use, return tools promptly to their proper place in the toolbox. Whenever tools become broken or damaged, they should be repaired or replaced. Any spare time between work assignments should be utilized for tool repairs and cleaning.

Responsibility

Most handtools are not feasibly repairable. Due to this fact and their original low cost (compared to power and special tools), they are classed as consumable. However, the activity must pay for replacements. Therefore, it is the duty of each individual to help eliminate the need for replacements. One method of accomplishing this is by carrying an inventory of tools in each toolbox so that upon completion of a job all tools can be accounted for. A tool that has been lost represents a waste of funds;

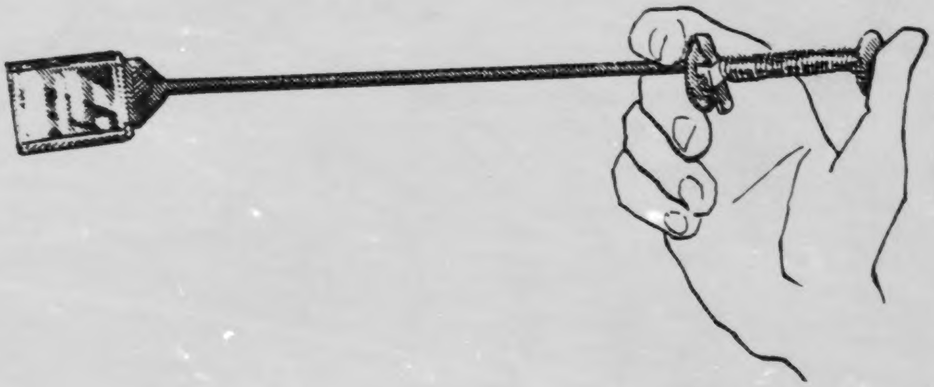

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Figure 5-13.–Typical inspection mirror.

in addition, it is a definite liability. If it has been left loose in an aircraft, it can become a dangerous missile when the aircraft is launched or when the aircraft is performing violent maneuvers.

Frequently a squadron tool crib has the responsibility for all tools in the squadron. This includes issuance, inventory of toolboxes, and ordering new tools for replacement of broken or lost tools.

Inventory Requirements

The basic objective of an inventory is to insure a proper balance between the supply of, and the demand for, those tools required for the efficient operation and maintenance of a squadron or maintenance activity. To accomplish this objective it is necessary that tools be identified and cataloged to provide accurate knowledge of the tools being used. Each item should be accounted for every 30 to 90 days in accordance with squadron instructions. The number of handtools on hand in relation to the number required by the activity should be indicated by the inventory.

Reordering

Tools are reordered as the inventory requirements dictate. Usually the senior petty officer or his delegate reorders all tools, both work center tools and those for individual toolboxes, as they are needed. However, squadron or maintenance activity policy is followed in all cases.

It is unwise to wait until the number of tools needed is too large, as it is easier for the supply department to fill a small order rather than a large one.

POWER TOOLS

Power tools may be divided into two general classes—electric and pneumatic. In aviation, a third type will be used occasionally—hydraulic power tools.

Navy safety regulations require that the casings of all electrically driven tools be grounded. This regulation is for the protection of the operator. People have actually been electrocuted by ordinary house current when using tools whose casings were not properly grounded. Electric tools used in the Navy must have a three-prong plug, the third prong being the ground.

Pneumatic tools are driven by compressed air. When it is necessary to use power tools inside or on an aircraft, pneumatic tools are preferred over electric tools, because an electric spark might start a fire. In an area where gasoline fumes may be suspected, electric tools are prohibited.

Pneumatic tools that are equipped with torque devices should not be used for the final torquing of nuts or studs. The torque of the pneumatic tool or nut runner, as it is commonly called, should be set at a lower torque value than specified for the nut or bolt, and then a hand torque wrench should be used for the final torque.

Hydraulic powered wrenches are used when high torque values are required, such as 2,000 or 3,000 foot-pounds. These wrenches have a hand pump for building up pressure to turn the nut and a pressure gage, usually calibrated in foot-pounds, for indicating the amount of torque applied. When using any type of hydraulic power tool, be sure that the work is held securely and that the tool fits the nut properly.

SPECIAL TOOLS

This category of tools is not part of the individual toolbox. Special tools are normally maintained in a central toolroom and signed out when needed. A tool falls into the special category for the following five main reasons:

1. It is an item of Special Support Equipment that was designed, manufactured, procured, stocked, and issued for the purpose of maintaining one model of aircraft, engine, or a particular piece of equipment.
2. It is a seldom used tool, and the majority of time it would merely take up room in the toolboxes. However, when needed, its use is essential in aircraft maintenance.
3. It is a high cost item, and to insure better utilization of each of this kind, fewer are available.
4. The awkward size and the shape of the tool make it extremely difficult, if not impossible, to issue one to each ADR to carry around in his toolbox.

5. It is an instrument type of tool that depends upon precise calibration for its usefulness. It could be knocked out of adjustment if subjected to the normal handling of an ADR toolbox.

Of course, a special tool may be covered under more than one or even all of the foregoing categories.

Special tools are listed in Allowance Lists published by the Naval Air Systems Command, and their use is explained in the Technical Manuals covering the particular aircraft, engine, or piece of equipment for which they were designed.

Sweeney Powerwrench

The Sweeney Powerwrench is used in the removal and installation of propellers. It has a number of adapters that will adapt the wrench to any size propeller shaft and propeller retaining nut. This wrench is a double gear reduction wrench with which it is possible to torque the retaining nut to the exact amount of required torque. It is used in conjunction with the standard 3/4-inch drive torque wrench. Care must be maintained to adhere to the torque values that are listed on the plate adjacent to the handle. This wrench can also be used to loosen or tighten the engine thrust bearing nut. (See fig. 5-14.)

Main Oil Strainer Assembly and Disassembly Tool

An ADR will often have the job of disassembling and cleaning the main oil strainer of the engine and then reassembling it to the specified limits. This job is best accomplished whenever the special tool designed for this purpose is used. The strainer assembly is placed within the tool and pressure is then used to compress the strainer sufficiently to enable you to use the special pliers to remove the lockring that holds the strainer assembly together. After the strainer screens are cleaned and the strainer itself is ready to be assembled, the tool is again used to complete the final assembly. (See figs. 5-15 (A) and 5-15 (B).)

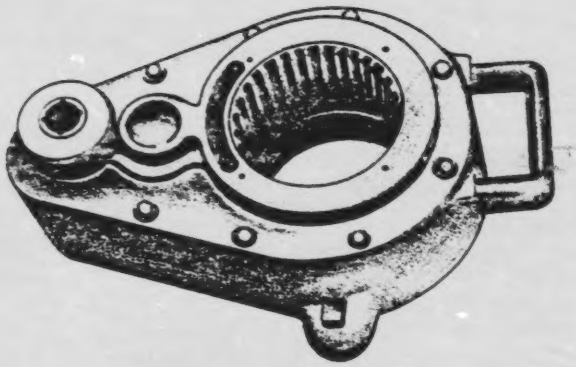

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Figure 5-14.–Powerwrench.

WORK CENTER TOOLS AND TOOL CRIBS

Work center tools are the larger, low-usage, and special tools for use on special

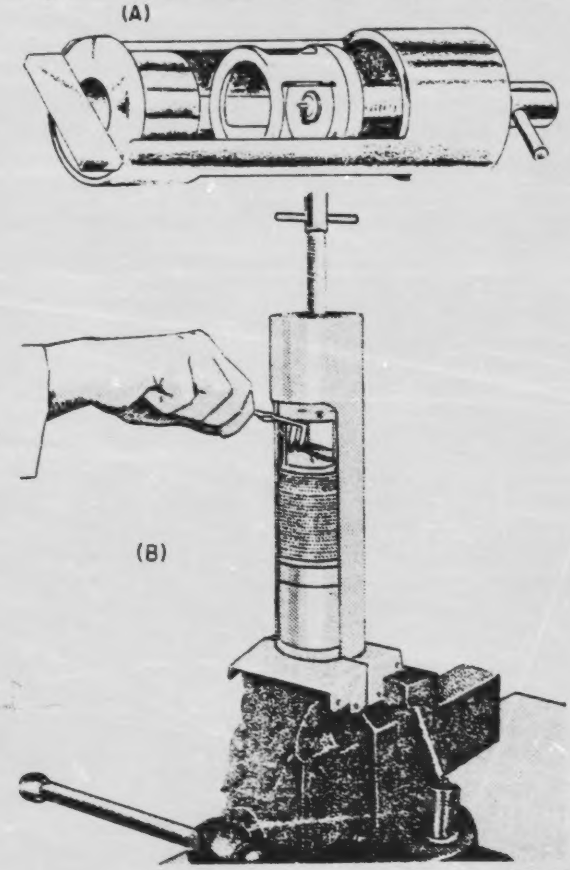

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Figure 5-15.—(A) Main oil strainer assembly and disassembly tool; (B) main oil strainer assembly in the tool showing removal of lockring.

equipments. A work center tool crib is normally utilized to make available those special tools needed to perform various phases of work center maintenance. However, work center tools also include any handtools required to perform more extensive maintenance than can be accomplished from a toolbox. The work center tools are determined by the size and type of the activity and by the allowance set forth in the Section G Allowance List.

Tools used in an aircraft maintenance activity are determined by the mission of the activity and the type of aircraft to be maintained. In view of this, there is no hard and fast rule as to the type and/or number of tools that may be supplied in the different toolboxes and tool cribs.

A squadron (or activity) tool crib is often established under the responsibility of the maintenance department. Its purpose is for the stowage and issue of low-usage handtools and those tools which are common to more than one work center. Many special tools which are provided by the aircraft manufacturer are also stowed in the tool crib. A complete list of these special tools can be found in the Maintenance Instructions Manual, section one, for each type aircraft and engine.

TORQUE WRENCHES

There are times when, for engineering reasons, a definite pressure must be applied to a nut. In such cases a torque wrench must be used. The torque wrench is a precision tool consisting of a torque-indicating handle and appropriate adapter or attachments. It is used to measure the amount of turning or twisting force applied to a nut, bolt, or screw.

The three most commonly used torque wrenches are the Deflecting Beam, Dial Indicating, and Micrometer Setting types (fig. 5-16). When using the Deflecting Beam and the Dial Indicating torque wrenches, the torque is read visually on a dial or scale mounted on the handle of the wrench.

To use the Micrometer Setting type, unlock the grip and adjust the handle to the desired setting on the micrometer type scale, then relock the grip. Install the required socket or adapter to the square drive of the handle. Place the wrench assembly on the nut or bolt and pull in a clockwise direction with a smooth, steady motion. (A fast or jerky motion will result in an improperly torqued unit.) When the torque applied reaches the torque value which is indicated on the handle setting, the handle will automatically release or "break" and move freely for a short distance. The release and free travel is easily felt, so there is no doubt about when the torquing process is complete.

To assure getting the correct amount of torque on the fasteners, all torque handles must be tested at least once a month or more often if usage indicates it is necessary.

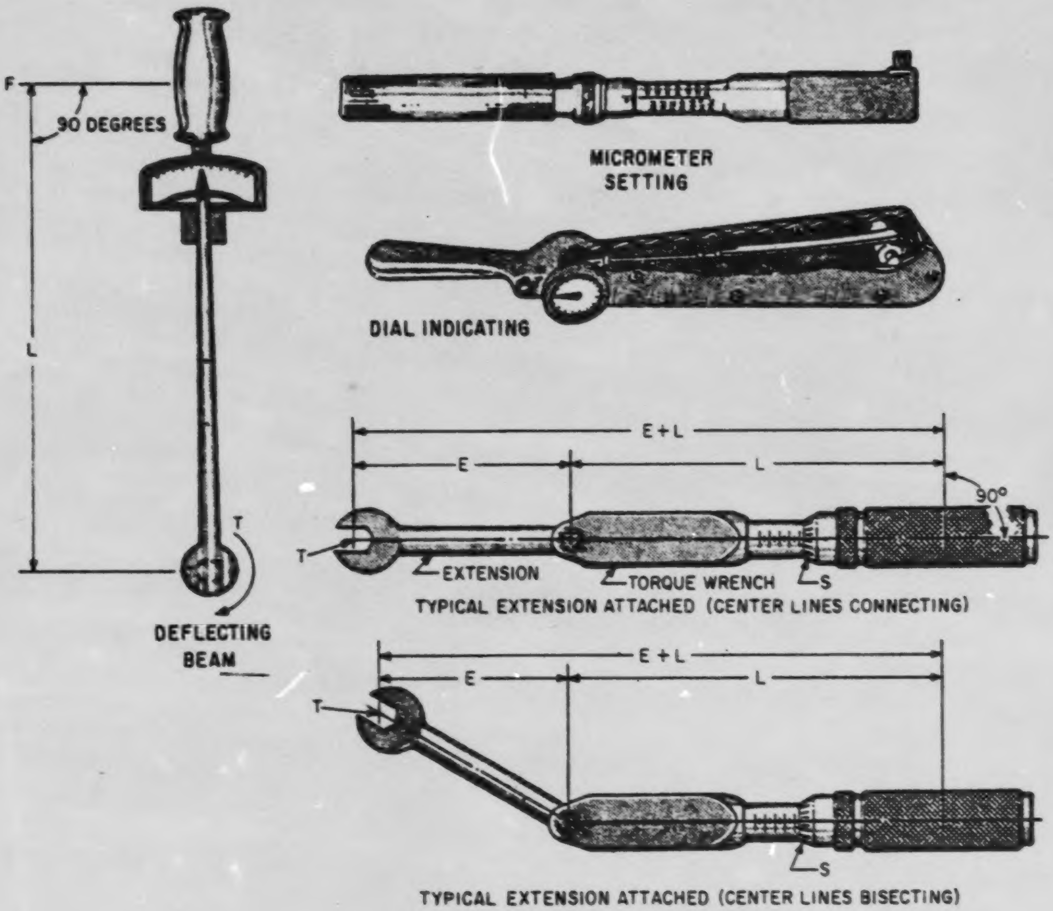
The following precautions should be observed when using torque wrenches:

1. Do not use the torque wrench as a hammer.
2. When using the Micrometer Setting type, do not move the setting handle below the lowest torque setting. However, it should be placed at its lowest setting prior to returning to storage.
3. Do not use the torque wrench to apply greater amounts of torque than its rated capacity.
4. Do not use the torque wrench to break loose bolts which have been previously tightened.
5. Never store a torque wrench in a toolbox or in an area where it may be damaged.

TORQUE VALUES

Torquing can be described as the twisting stress that is applied to the fasteners to secure components together. These fasteners can be nuts, bolts, studs, clamps, etc. Torque values for these fasteners are expressed in inch-pounds or foot-pounds. Unless otherwise stated, all torque valves should be obtained with the manufacturer's recommended thread lubricant applied to the threads.

Torque valves are usually found in the table of limits section of the Service Instructions Manuals. This one section contains most of the torque value information needed for the repair of the engine and should be referred to when any torque values are needed. However, in case there is no torque specified, the torque values in table 5-1 can be used as a guide in tightening nuts, bolts, and screws. Using the proper torque allows the structure to develop its designed strength and greatly reduces the possibility of failure due to fatigue. One word of caution–never rely on memory for torque infor-


F
90 DEGREES
L
T
DEFLECTING BEAM
MICROMETER SETTING
DIAL INDICATING
E+L
E
L
90°
T
EXTENSION
TORQUE WRENCH
S
TYPICAL EXTENSION ATTACHED (CENTER LINES CONNECTING)
E+L
E
L
T
S
TYPICAL EXTENSION ATTACHED (CENTER LINES BISECTING)

AD.15

Figure 5-16.—Torque wrenches.

mation, but look up the correct torque value each time it is needed. A nut or bolt that is not torqued to the proper torque value may cause the loss of an engine or aircraft.

The proper procedure is to tighten at a uniformly increasing rate until the desired torque is obtained. In some cases, where gaskets or other parts cause a slow permanent set, the torque must be held at the desired value until material is seated. When applying torque to a series of bolts on a flange or in an area, select a median value. If some bolts in a series are torqued to a minimum value and others to a maximum, force is concentrated on the tighter bolts and is not distributed evenly. Such unequal distribution of force may cause shearing or snapping of the bolts.

Torque wrench size must be considered when torquing. The torque wrenches are listed according to size and should be used within this recommended range. Use of larger wrenches which have too great a tolerance results in inaccuracies. When an offset extension wrench (crowfoot) is used with a torque wrench, the effective length of the torque wrench is changed. The torque wrench is so calibrated that when an extension is used, the indicated torque (the torque which appears on a dial or gage on the torque wrench) may be different from the actual torque that is applied to the nut or bolt. There-

Table 5-1.–Torque value in inch-pounds for standard nuts, bolts, and screws.

Wrench size	Standard nuts, bolts, and screws		
	Bolt, stud, or screw size	Tension type nuts AN310 and AN365	Shear type nuts AN320 and AN364
1/4	4-48	4-5.5	2.5-3.5
5/16	6-40	7.5-11	4.5-6.5
11/32	8-36	12-15	7-9
3/8	10-32	20-25	12-15
7/16	1/4-28	50-70	30-40
1/2	5/16-24	100-140	60-85
9/16	3/8-24	160-190	95-110
5/8	7/16-20	450-500	270-300
3/4	1/2-20	480-690	290-410
7/8	9/16-18	800-1,000	480-600
15/16	5/8-18	1,100-1,300	660-780
1 1/16	3/4-16	2,300-2,500	1,300-1,500
1 1/4	7/8-14	2,500-3,000	1,500-1,800
1 7/16	1-14	3,700-5,500	2,200-3,300

NOTE: AN specification numbers may be superseded by MS specification numbers.

fore, the wrench must be present to compensate for the increase when an offset extension wrench is used-the torque or decrease in actual torque as compared to indicated torque.

Occasionally, it is necessary to use a special extension or adapter wrench together with a standard torque wrench. In order to arrive at the resultant required torque limits, the following formula should be used:

$$S = \frac{T \times L}{(E + L)}$$

Where:

S=Reading of setting on torque wrench.
T=Recommended torque on part.
L=Length of torque wrench (distance between center of drive and center of grip)
E=Length of extension of adapter (distance between center of drive and center of broached opening measured in the same place as L).

EXAMPLE: Recommended torque is 100 inch-pounds. Using a torque wrench and a 6-inch adapter, determine reading on torque wrench.

$$S = \frac{100 \times 12}{(6 + 12)} = \frac{1200}{18} = 66.6 \text{ inch-pounds}$$

Figure 5-16 shows some torque wrenches and an example of the measuring for the above formula. When the estension is pointed back toward the handle of the torque wrench, subtract the effective length of the torque wrench. If the extension is pointed at a right angle to the torque wrench, then the actual value does not change.

It is not advisable to use a handle extension on a deflecting beam type torque wrench at any time. A handle extension alone has no effect on the reading of the other types. The use of a drive and extension on any type of torque wrench makes the use of the formula mandatory. When applying the formula, force must be applied to the handle of the torque wrench at the point from which the measurements were taken. If this is not done, the torque obtained will be in error.

SELECTION AND USE OF AIRCRAFT HARDWARE

Aircraft hardware is the term used in reference to a great many items used in aircraft and powerplants construction. These include fasteners, couplings, clamps, brackets, fittings, bolts, nuts, washers, wire and cables, and related hardware.

Because of the small size of most hardware items, their importance is often overlooked; however, the safe and efficient operation of any aircraft is greatly dependent upon correct selection and use of aircraft hardware. This section discusses these various items, and provides information which will aid in the selection and correct use of aircraft hardware.

TUBING

Since weight elimination is vital in aircraft design, the majority of rigid tubing used for hydraulic and pneumatic systems is manufactured from aluminum alloy. However, exposed lines and lines subject to abrasion or intense heat are made of stainless steel. Therefore, the ADR will be concerned more with stainless steel lines. When an engine fuel line requires replacement, the normal procedure is to draw a preformed line, with fittings attached to replace the defective line. If a line must be manufactured locally and installed on an engine or component, the following procedures should be followed:

Lines should normally be kept as short and free of bends as possible. However, tubing should not be assembled in a straight line, because a bend tends to eliminate strain by absorbing vibration and compensates for thermal expansion and contraction. Bends are preferred to elbows, because bends cause less of a power loss. A few of the correct and incorrect methods of installing tubing are illustrated in figure 5-17.

Hose is used in aircraft where there is a necessity for flexibility, such as connections to units that move while in operation, or to units attached to a hinged portion of the equipment. It is also used in locations that are subjected to severe vibration. The following steps are general procedures for installing flexible hose. Figure 5-18 shows the correct and incorrect installation of flexible hose.

1. Do not use oil on any self-sealing hose to aid in installation. Oil or water may be used on all other types of fuel, oil, and coolant hose during the installation procedure; however, water should not be used when installing hydraulic or pneumatic type hose.
2. Install the hose so that it will not be subject to twisting under any operating condition.

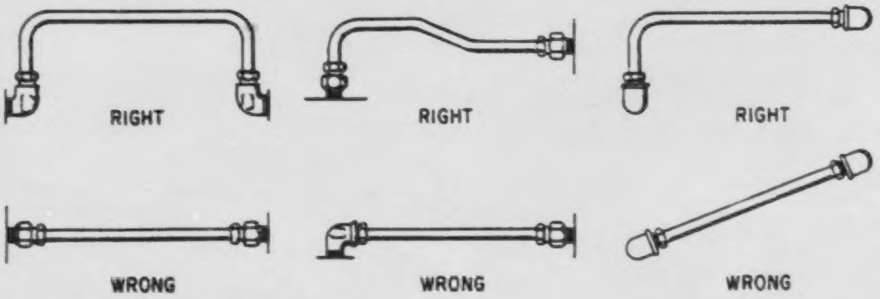


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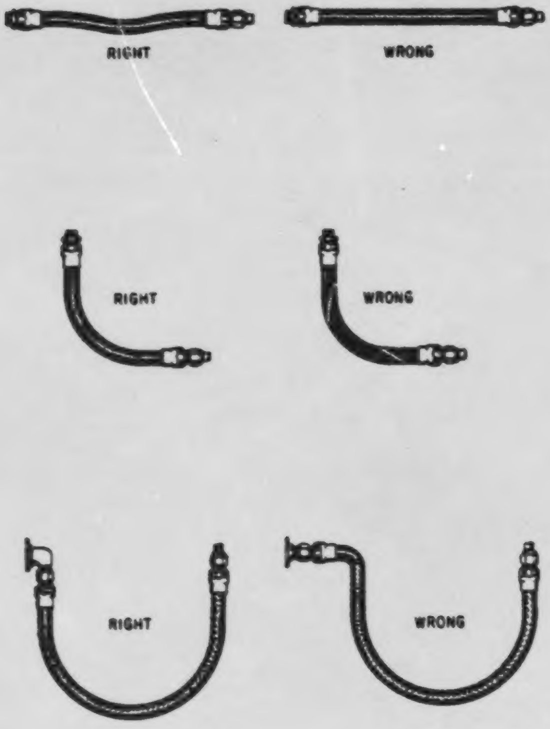
Figure 5-17.—Correct and incorrect methods of installing tubing.



AD.33

Figure 5-18.—Correct and incorrect installation of flexible hose.

This in itself will be a deterrent to prevent the fittings from loosening. When replacing any hose in the oil, fuel, hydraulic, alcohol, water injection, and pneumatic systems, the hose that is installed should be the exact duplicate of the hose that has been removed as to length, outside diameter, inside diameter, material, type, and contour unless otherwise directed.

3. When it is necessary to create bends in the hose to pass around objects, always be certain that the minimum radii permitted are not exceeded. Bend radii tables for all types of installations are contained in Aircraft Structural Hardware, NA 01-1A-8.

4. Do not use clamps or supporting clips that are smaller than the outside diameter of the hose. If smaller clamps are used, it may restrict the flow of the fluid through the hose and damage may occur.

5. Support the hose at least every 24 inches. (Closer supports are preferred.) Support the hose so that it will not cause any deflection of the rigid connecting points. Flexible hose should never be rigidly supported or allowed to have too much excessive motion.

6. Eliminate all chafing points by using suitable type supports and insuring adequate clearance.

7. Protect all flexible hoses from excessive temperatures by either installing shrouds around them or relocating the lines so that they will not be affected. Use flame-resistant hose forward of the firewall as directed by applicable instructions.

8. Where hose connections are made to the various engine driven accessories, install the hose so that there is an adequate amount of slack in the hose to prevent the possibility of the hose being pulled off the nipple of the fitting to which it is attached.

9. Whenever a length of hose is connected to the engine with a hose clamp, firmly support the hose in a manner that will prevent vibrational and torsional strain on the hose connection. If possible, place the support approximately 3 inches from the engine connection.

10. If possible, install the hose or hose assembly so that the markings on the hose are visible.

Hose and hose assemblies should be checked at each inspection period for deterioration. Leakage, separation of the cover or braid from the inner tube, cracks, hardening, lack of flexibility, and excessive cold flow are apparent signs of deterioration and reason for replacement. Cold flow is indicated by deep, permanent impressions and cracks in the hose cover produced by the pressure of the hose clamps or supports.

IDENTIFICATION OF FLUID LINES

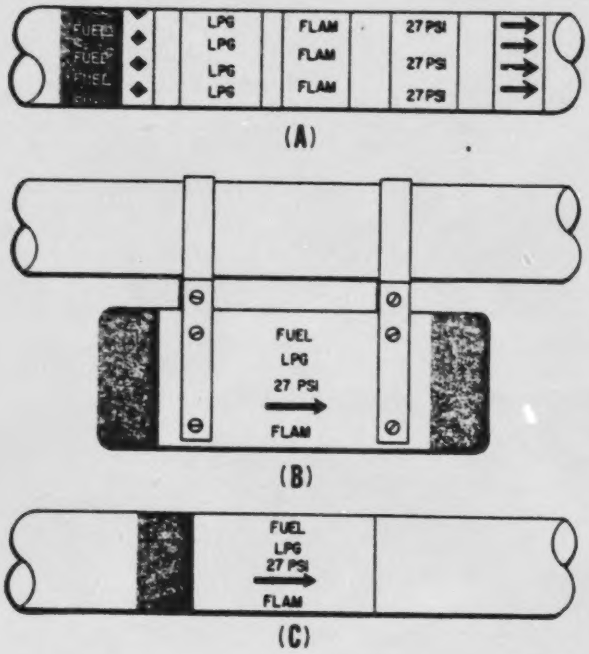
Fluid lines in aircraft are identified by markers made up of color codes, words, and geometric symbols. These markers identify each line as to its function, content, primary hazard, and direction of flow. Figure 5-19 lists the various types of fluid lines and indicates the color code and symbol for each line. Figure 5-20 illustrates the markers as used for fuel lines.

In most instances, lines are marked by the use of 1-inch tape or decals, as shown in figure 5-20 (A). On lines 4 inches and larger

FUNCTION	COLOR	SYMBOL
Fuel	Red	✦
Rocket Oxidizer	Green, Gray	)
Rocket Fuel	Red, Gray	✦)
Water Injection	Red, Gray, Red	⌄
Lubrication	Yellow	⁚
Hydraulic	Blue, Yellow	●
Solvent	Blue, Brown	≣
Pneumatic	Orange, Blue	⧗
Instrument air	Orange, Gray	⟩
Coolant	Blue	~
Breathing Oxygen	Green	▬
Air Conditioning	Brown, Gray	⁘
Monopropellant	Yellow, Orange	T
Fire Protection	Brown	◆
De-Icing	Gray	▲ ▲
Rocket Catalyst	Yellow, Green	|||
Compressed gas	Orange	▰
Electrical Conduit	Brown, Orange	↯
Inerting	Orange, Green	++

AM.67

Figure 5-19.—Fluid line color codes and symbols.



AD.21

Figure 5-20.–Fluid line identification group. (A) Using tape and decals; (B) using metal tags; (C) using paints.

in diameter, lines in an oily environment, hot lines, and on some cold lines, steel tags may be used in place of tape or decals. (See fig. 5-20 (B).) On lines in engine compartments, where there is the possibility of tapes, decals, or tags being drawn into the engine induction system, paint is used. (See fig. 5-20(C).)

As can be seen in figure 5-20(A), reading from left to right, the line function is indicated by color code (red), name (fuel), and symbol (4-pointed star). Content of the line is indicated by the name (LPG (liquid petroleum gas)); the primary hazard is indicated by the word FLAM; pressure is indicated in pounds per square inch (27 psi); and the direction of flow is indicated by arrows. (Two-headed arrows are used to indicate reversible flow where applicable.) In addition to the above mentioned markings, certain lines may be further identified as to specific function within a system; for example, DRAIN, VENT, PRESSURE, RETURN, etc., as the case may be.

Lines containing toxic materials are marked TOXIC in place of FLAM; lines containing physically dangerous materials such as oxygen, nitrogen, Freon, etc., are marked PHDAN; and anesthetics and certain other harmful materials are marked AAHM.

The aircraft and engine manufacturers are responsible for the original installation of identification markers, and maintenance personnel are responsible for replacement when it becomes necessary.

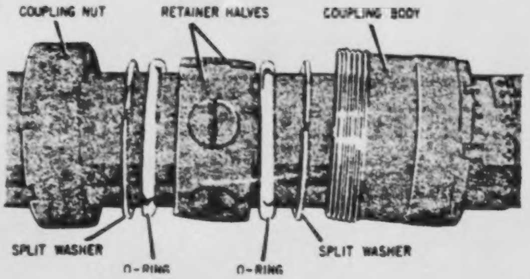
As a general rule, tapes and decals are placed on both ends of a line and at least once in each compartment through which the line runs. In addition, identification markers are placed immediately adjacent to each valve, regulator, filter, or other accessory within a line. Where tags or paints are used, location requirements are the same as for tapes and decals.

Complete instructions for installing fluid line identification markers are contained in MIL-STD-1247.

COUPLINGS

The purpose of the coupling is to couple or connect the ends of adjacent parts or lines. The coupling also allows for slight misalignment of the two parts to be connected. It acts, to a slight degree, as a universal joint. There are several different types of coupling installations on aircraft engines, and one of the most common is shown in figure 5-21. This is a flexible line installation and care should be exercised when working with this coupling.

The ADR must use the proper type spanner wrench when removal or installation procedures are involved. Care should also be exercised with the working parts of the coupling



AD.16

Figure 5-21.–Flexible line coupling.

such as the O-ring, split washer, and retainer halves. Insure that a new O-ring is used on installation and that it has been lubricated properly. The parts should be installed as shown in figure 5-21. Then the coupling nut and the coupling body should be slid together over the retainer halves. The threads should then be engaged and the unit turned down by hand until tight. The coupling should then be tightened to the proper torque value and lockwired.

The flexible half coupling is shown in figure 5-22. It is similar to the flexible line coupling except for the use of a split washer on either side of the O-ring seal.

CLAMPS

The clamps found on aircraft are used for preventing lines from chafing on parts or against other lines and to connect two lines or pieces of material.

One type of clamp and its use in supporting flexible and rigid lines can be seen in figure 5-23. These clamps should be checked for deterioration of the rubber to prevent the metal part of the clamp from cutting into the outside wall of the hose it is supporting. In selecting a clamp for an installation, the ADR should choose one that is the proper size and in good material condition.

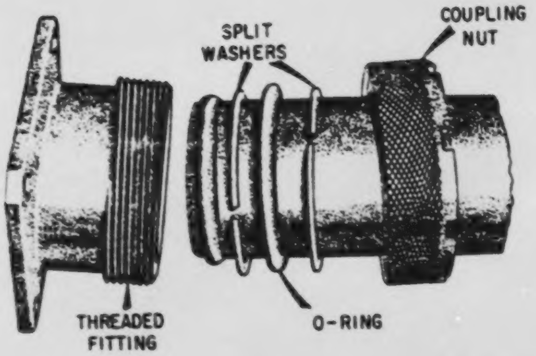


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Figure 5-22.–Flexible half coupling.

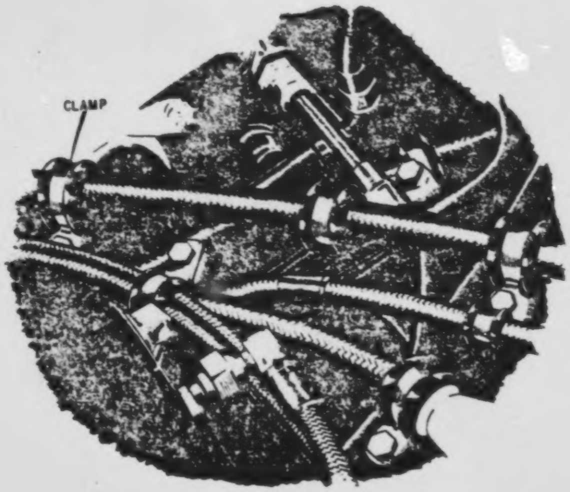

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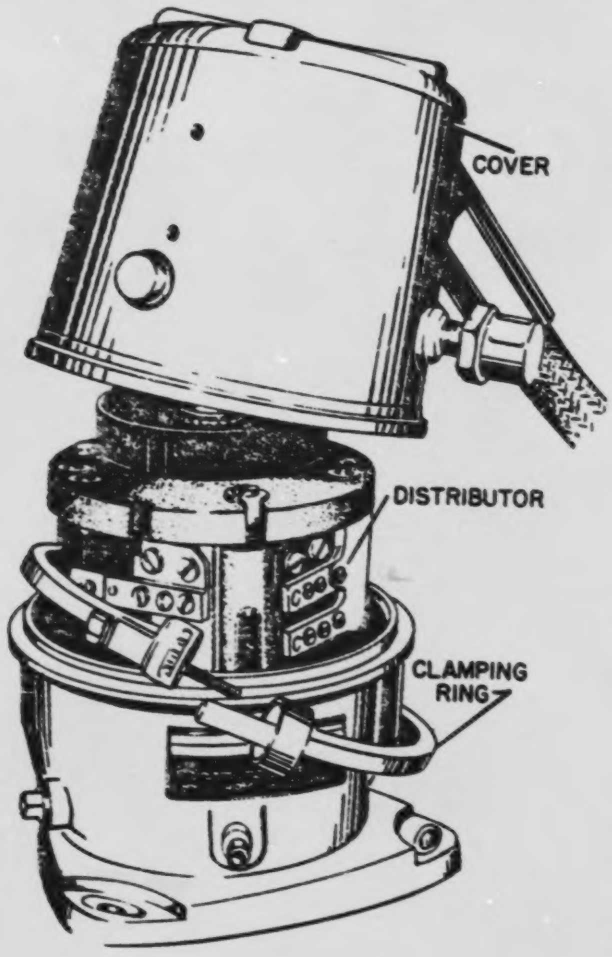
Figure 5-23.–Clamps.

Figure 5-24 shows the type clamp used to secure the distributor cover to the distributor base. A clamp very similar is used to secure the magneto generator cover.

Another type of clamp that the ADR may be using is the Ideal hose clamp. This clamp may be used on any type of clamp installation on the aircraft. It is considered two-blocked if the tips come closer than three-sixteenths of an inch. When installing this type clamp, the excess strap should be cut off to prevent possible breakage due to vibration.

The radial hose clamp is a stainless steel strip spotwelded on the saddle of the Ideal hose clamp. It comes in sizes 22 to 82 inclusive and it may be used on fuel and oil lines. The larger sizes are not to be used on fuel and oil lines, but they may be used on other installations.

When installing hose clamps, always allow a minimum distance of one-fourth of an inch aft of the bead on the line or fitting. The minimum amount of hose extending past the last clamp is one-fourth of an inch. Minimum distance between clamps is three-eights of an inch if two clamps are required on each side of the connection.



AD.27

Figure 5-24.–Distributor cover clamp.

When hose clamps are installed, they should be tightened to the torque value specified in the appropriate Service Instructions Manual. Usually the torque on self-sealing hose is 15 inch-pounds with a torque wrench or finger tight plus 2 1/2 turns without a torque wrench. Hoses should be braced or supported at least every 24 inches.

TURNLOCK FASTENERS

There are several different types of turnlock fasteners with which the ADR will come in contact. The Camloc, Dzus, and Airloc are just a few of the types that are used to secure inspection plates, doors, and other removable panels on the aircraft or engine nacelle. These turnlock fasteners are also referred to by such terms as quick-opening, quick-acting, and stress panel fasteners. The most desirable feature of these fasteners is that they permit quick and easy removal of access panels and doors for inspection and servicing.

Camloc Fasteners

Camloc fasteners are made in a variety of sizes and shapes. They are carried in a numbered series in the regular line, and also in the stressed-panel fastener in the heavy-duty line (SPF). The latter fastener is used in stressed panels that carry heavy structural loads.

A quarter turn of the stud (clockwise) locks the fastener. The fastener may be unlocked only by turning the stud counterclockwise. (See fig. 5-25.)

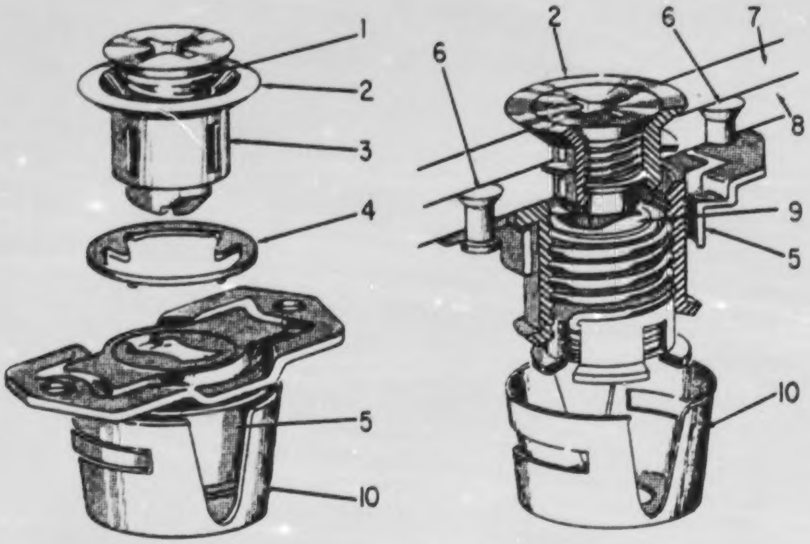
Dzus Fasteners

The Dzus fastener consists of a rotatable stud, which may have a slot for a screwdriver, or it may have a winged fitting on it for opening and closing without a tool. It also has a permanently mounted spring and a grommet. The stud and grommet are mounted in the door or other removable part, and the spring is riveted to the frame of the access on which the door fits.

Cams on the stud engage with the spring to lock the fastener in the engaged position. The purpose of the grommet is to retain the stud in the access door. In some installations, the grommet is not used as a retainer; the stud is secured to the access door by a snap-ring, cup washer, or by dimpling of the metal around the stud.

A quarter turn of the stud in a clockwise direction will lock it into position. It may be opened by turning counterclockwise.

This type of fastener may be opened and closed with a screwdriver, but it has a special tool called a Dzus key, designed for the opening and closing process. See figure 5-26 for an illustration of the Dzus fastener.



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1. Tension spring.
2. Stud assembly
3. Bushing.
4. Retaining ring.
5. Receptacle assembly.
6. Receptacle attaching rivits.
7. Outer skin.
8. Inner skin.
9. Insert.
10. Cover.

Figure 5-25.—Camloc fastener.

Airloc Fasteners

The Airloc fastener consists of a stud, stud cross pin, and a receptable. (See fig. 5-27.) The stud is attached to the access cover and is held in place by the cross pin. The receptable is riveted to the access cover frame. A quarter turn of the stud (clockwise) locks the fastener in place; counterclockwise unlocks it.

BRACKETS

The bracket is used to mount a part or unit to a structure or other body to support weight. An example of a bracket is shown in figure 5-28(A). This type of bracket is used to support a line, usually metal tubing, and the line is either brazed or welded to the bracket. Figure 5-28(B) shows another line mounting bracket; however, on this type bracket the elbow that mounts the line swivels to allow for various types of installations. Figure 5-28(C) shows a straight type line mounting bracket.

Another type of bracket is the mounting bracket shown in figure 5-29. This installation is used to provide a mount for a component. When making an installation of this type, care must be exercised to insure that all nuts, bolts, and other parts of the bracket do not

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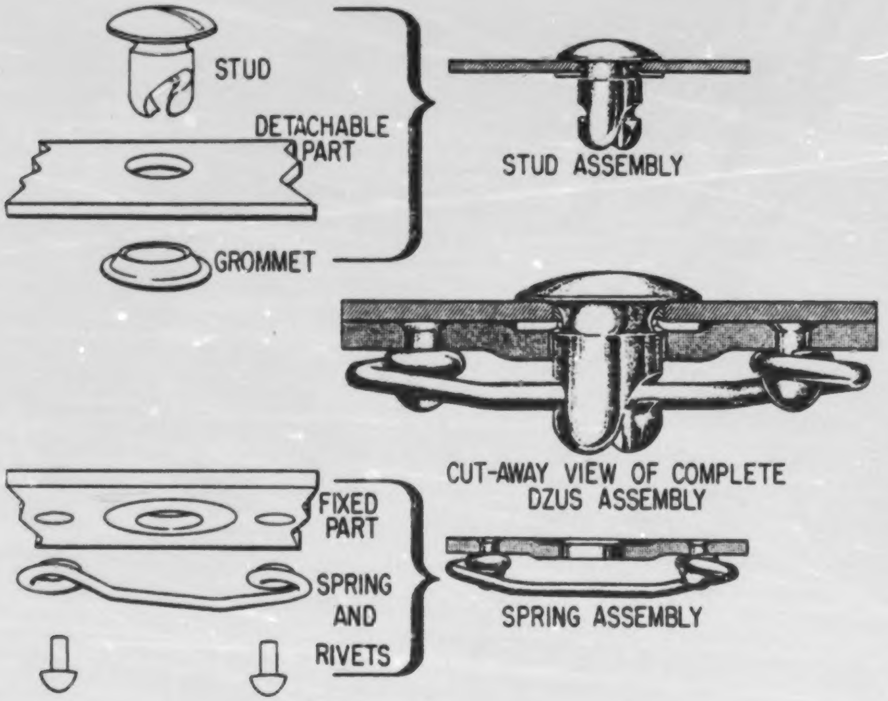
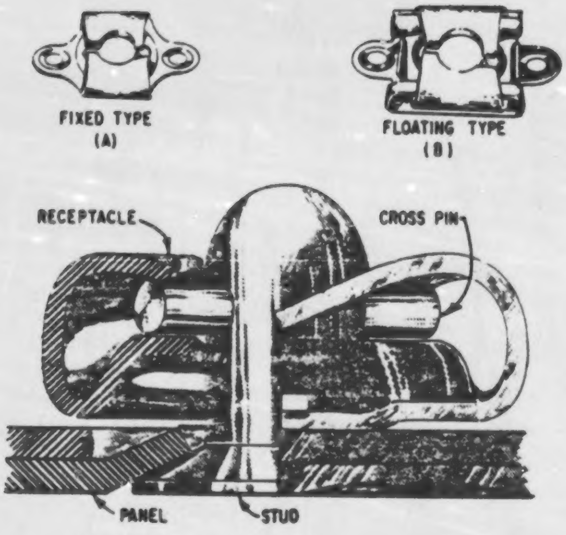

STUD
DETACHABLE PART
GROMMET
STUD ASSEMBLY
CUT-AWAY VIEW OF COMPLETE DZUS ASSEMBLY
FIXED PART
SPRING AND RIVETS
SPRING ASSEMBLY

AD.22

Figure 5-26.–Dzus fastener.


FIXED TYPE (A)
FLOATING TYPE (B)
RECEPTACLE
CROSS PIN
PANEL
STUD

AM.40

Figure 5-27.–Airloc fastener.

rub or restrict the action of other structural members.

ADAPTERS

The word "adapter" is usually defined as a device for connecting two pieces of apparatus or lines of two different sizes. Figure 5-30 shows adapters being used to connect hydraulic ground test lines into the aircraft.

THREADED FASTENERS

Many parts of the aircraft engine require frequent dismantling or replacement when the engine is being inspected. This makes it practical to use some type of threaded fastener, enabling the mechanic to complete the job in a reasonable amount of time. This problem is solved by the manufacturer through the use of various types of screws, nuts, and bolts.

Bolts and screws are similar because both have a head at one end and a screw thread at

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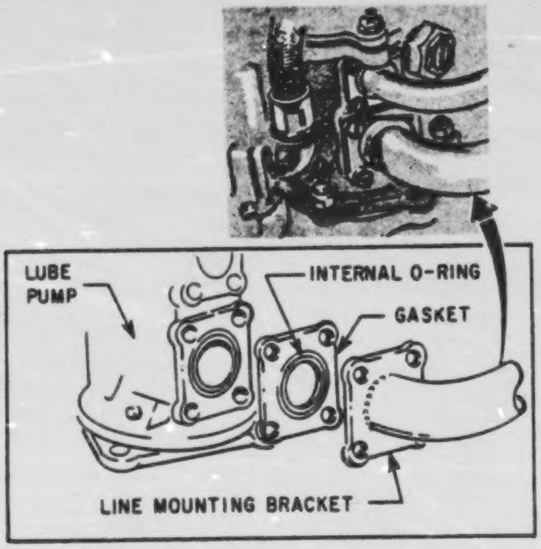
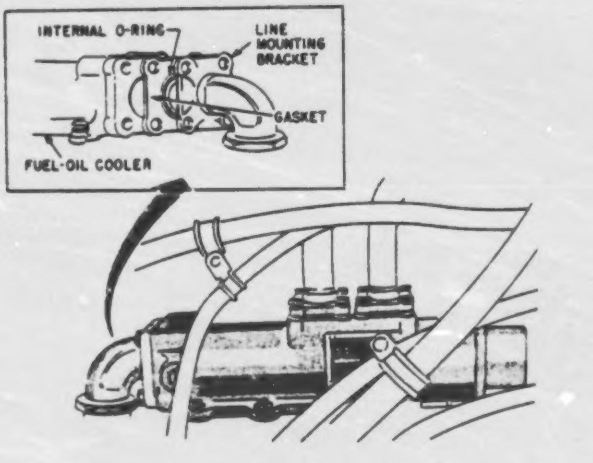

LUBE PUMP
INTERNAL O-RING
GASKET
LINE MOUNTING BRACKET
(A)

AD.24

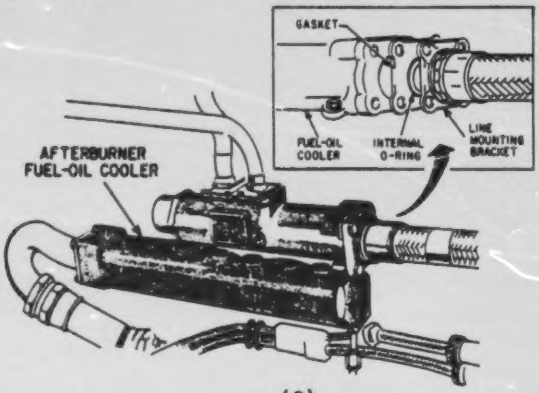
Figure 5-28.–(A) Line mounting bracket, rigid angle.

the other. However, there are several differences between them. The threaded end of a bolt is always blunt while that of a screw may be either blunt or pointed. The threaded end of a bolt must be screwed into a nut, but the threaded end of a screw may fit into a nut or other type of female arrangement, or may fit directly into the material being secured.


INTERNAL O-RING
LINE MOUNTING BRACKET
GASKET
FUEL-OIL COOLER
(B)

AD.24

Figure 5-28.–(B) Line mounting bracket, swivel angle.


GASKET
FUEL-OIL COOLER
INTERNAL O-RING
LINE MOUNTING BRACKET
AFTERBURNER FUEL-OIL COOLER
(C)

AD.24

Figure 5-28.–(C) Line mounting bracket, straight.

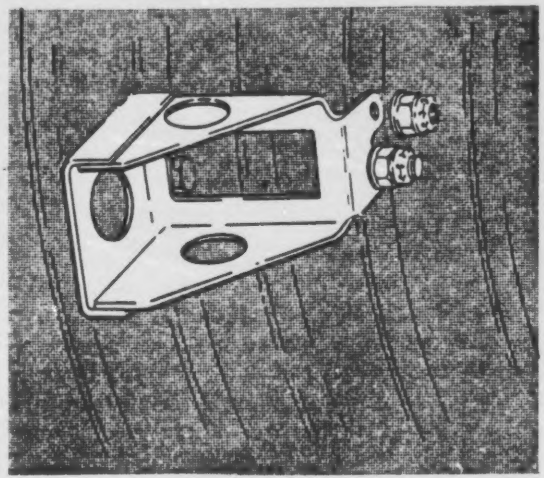


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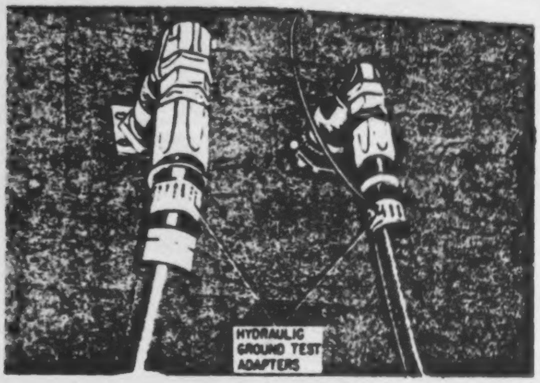
Figure 5-29.–Mounting bracket.

Classification of Threads

Threads on aircraft bolts and screws are of the American National Standard type. This standard contains two series of threads-national course (NC) series and national fine (NF) series. Most aircraft threads are of the NF series.

Threads are also produced in right-hand and left-hand types. The right-hand thread pattern is the one which you will come in



AD.26

Figure 5-30.–Hydraulic ground test adapter.

Table 5-2.—Threads per inch on commonly used bolt sizes.

Bolt diameter	Threads per inch	
	Coarse	Fine
1/4	20	28
5/16	18	24
3/8	16	24
7/16	14	20
1/2	13	20
5/8	11	18

contact with most frequently when maintaining aircraft engines.

Identification of Threads

Threads are designated by the diameter, number of threads per inch, thread series, and class in parts catalogs, on blueprints, and on repair diagrams.

For example, No. 8-36NF-3 indicates a No. 8 size diameter, 36 threads per inch, national fine series, and a class 3 thread. Also 1/4-20NC-3 indicates a 1/4-inch, 20 threads per inch, national coarse series, and a class 3 thread. A left-hand thread is indicated by the letters LH following the class of thread.

Table 5-2 shows the number of threads per inch on the most commonly used bolt sizes.

Nuts

The types of nuts used in the engine and aircraft structure are plain nuts, castle nuts, checknuts, plate nuts, channel nuts, barrel nuts, internal-wrenching nuts, external-wrenching nuts, shear nuts, sheet spring nuts, and wingnuts. Many of these nuts are available in either self-locking or nonself-locking style. They are made of cadmium-plated carbon steel, corrosion-resistant steel, brass, and anodized aluminum alloy.

Nuts are ordered separately from bolts and one means of identifying them is through the stock number in the catalog from which they are ordered. They also may be identified by color, weight, type of construction, and thread size.

Except for a few very special types, nearly all the nuts used in maintaining aircraft and engines are Air Force-Navy Standard. In the stocklists, the part numbers will designate the type of nut. The common types and the respective part numbers are: Plain, AN315 and AN334; Castle, AN310; Plain Check, AN316; Light Hex, AN340 and AN345; Castellated Shear, AN320; and Wing Nut, AN350.

The patented self-locking types are assigned part numbers ranging from AN363 through AN367. The BOOTS, FLEXLOC, FIBER LOCKNUT, ELASTIC STOPNUT, and the STEEL SELF-LOCKING belong to this group. Part number AN350 is assigned to the wingnut.

Letters and digits following the part number indicate such items as material, size, threads per inch, and whether the thread is right-hand or left-hand. The letter B following the part number indicates the nut material to be brass, a D indicates it to be 2017 aluminum alloy, a DD indicates it to be 2024 aluminum alloy, a C indicates it to be stainless steel, and a dash in place of a letter indicates the material to be cadmium plated carbon steel.

The digit (or two digits) following the dash or the material code letter is the DASH NUMBER of the nut and indicates the size of the shank and threads per inch of the bolt on which it will fit. The dash number corresponds to the first figure appearing in the part number coding of general purpose bolts. A dash number 3, for example, indicates that the nut will fit an AN3 bolt (10-32), a 4 means it will fit an AN4 bolt (1/4-28), a 5 indicates an AN5 bolt (5/16-24), and so on. Unless otherwise stated, threads per inch are given in national fine (NF) readings.

The code numbers for self-locking nuts end in three- or four-digit numbers. The last two digits refer to threads per inch and the one or two digits preceding these stand for the nut size in sixteenths of an inch.

In stocklists, the full code number is given for each nut and the corresponding bolt and thread size is also given in another column. If the description may be doubtful, an illustration is included. This arrangement makes the stocklist description quite complete and prevents errors when ordering nuts and bolts.

The nuts that are used on aircraft and engines can be divided into two general categories–NONSELF-LOCKING NUTS and SELF-LOCKING NUTS. Nonself-locking nuts are those which must be safetied through the use of cotter pins, safety wire, lockwashers, or locknuts. Self-locking nuts carry the locking feature as an internal part of the nut.

NONSELF-LOCKING NUTS.–Most of the familiar types of nuts, including the plain nut, the castle nut, castellated shear nut, plain hex nut, and the plain checknut are of the nonself-locking type. Figure 5-31 illustrates these various types of nonself-locking nuts.

The CASTLE NUT is used in conjunction with drilled-shank AN hex-head bolts, eyebolts, drilled head bolts, or studs. It is fairly rugged and can withstand large tensional loads. Slots (called castellations) in the nut are designed to accommodate a cotter pin or lock wire for safetying purposes.

The CASTELLATED SHEAR NUT is designed for use with such devices as drilled clevis bolts and threaded taper pins, which are normally subjected to shearing stresses only. Like the castle nut, it is castellated for safetying, but is not as deep nor as strong as the castle nut.

The PLAIN HEX NUT is of rugged construction. This makes it suitable for carrying large tensional loads. However, since it requires an auxiliary safetying device, such as a checknut or lockwasher, its use on aircraft and engine structures is very limited.

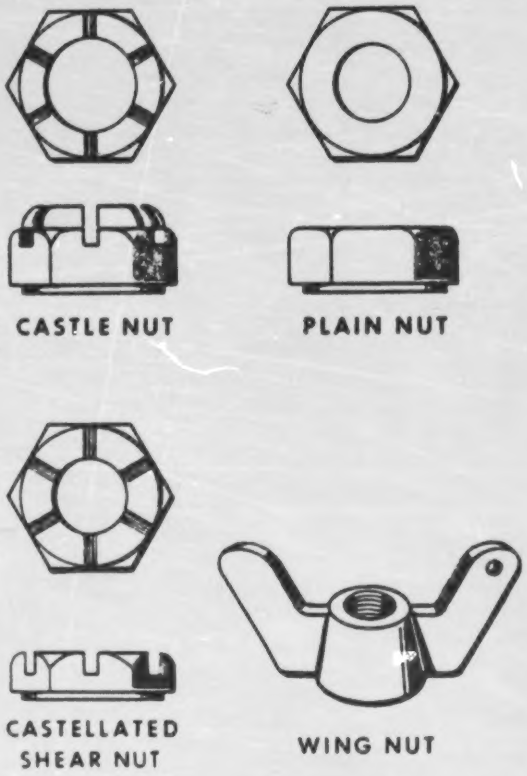


Figure 5-31.–Nonself-locking nuts.

The LIGHT HEX NUT is a much lighter nut than the plain hex nut and must be locked by an auxiliary device. It is used primarily for light, miscellaneous requirements.

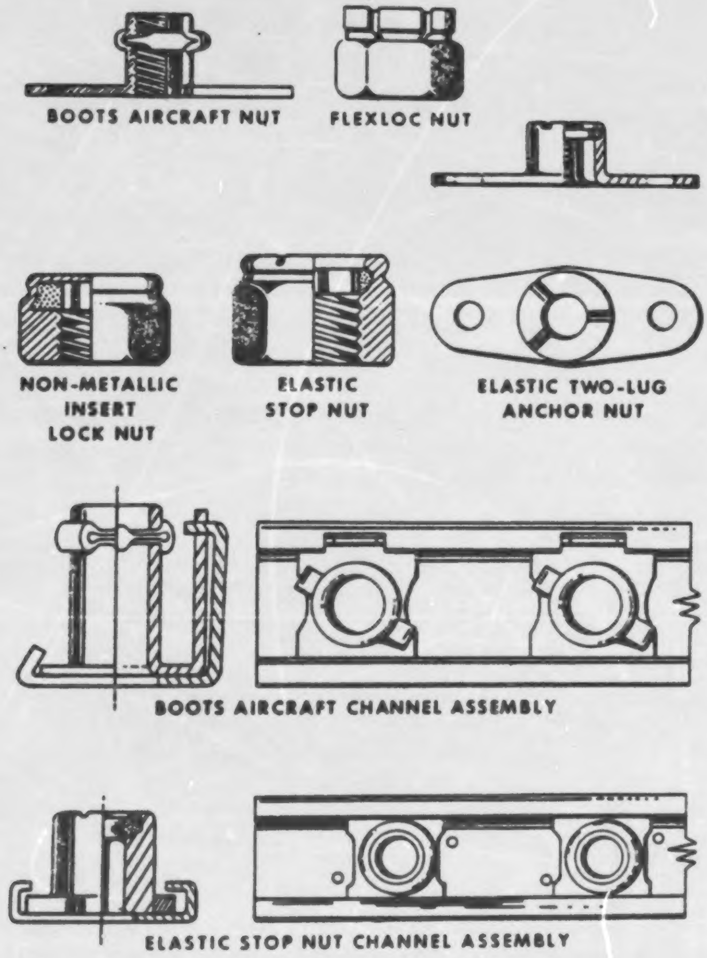
The PLAIN CHECKNUT is employed as a locking device for plain nuts, setscrews, threaded rod ends, and other devices.

WINGNUTS are used and intended only for places where the desired tightness can be obtained with the fingers and where the part or parts are often removed for checking, such as fuel strainers. Wingnuts are secured by lockwiring.

SELF-LOCKING NUTS.–There are two general types of self-locking nuts used currently in the maintenance of aircraft and engines–the ALL-METAL type and the NONMETTALIC INSERT type. The BOOTS and the FLEXLOC are examples of the all metal type; the ELASTIC STOP is an example of the nonmetallic insert type. Figure 5-32 shows several examples of self-locking nuts.

The BOOTS self-locking nut is of one-piece all-metal construction, designed to hold tight in spite of extreme vibration. It has two sections and is essentially two nuts in one—a locking nut and a load-carrying nut. The two sections are connected by a spring which is an integral part of the nut. The spring keeps the locking and load-carrying sections such a distance apart that the two sets of threads are out of phase; that is, so spaced that a bolt which has been screwed through the load-carrying section must push the locking section outward against the force of the spring in order to engage the threads of the locking section properly. Thus, the spring, through the medium of the locking section, exerts a constant locking force on the bolt in the same direction as a force that would tighten the nut. The nut can be removed and used again without impairing its efficiency. All metal self-locking nuts are designed to withstand temperatures up to 500°F, but no higher.

The ELASTIC STOPNUT is designed with a nonmetallic insert within it which locks the nut in place. When a bolt is run through the nut the bolt threads cut threads in the insert. There are two types of inserts presently in use—the NYLON insert and the FIBER insert. Both of these types of nuts are tough and durable.


BOOTS AIRCRAFT NUT
FLEXLOC NUT
NON-METALLIC INSERT LOCK NUT
ELASTIC STOP NUT
ELASTIC TWO-LUG ANCHOR NUT
BOOTS AIRCRAFT CHANNEL ASSEMBLY
ELASTIC STOP NUT CHANNEL ASSEMBLY

AM.44

Figure 5-32.—Self-locking nuts.

But, a nut of this type must be discarded whenever the insert loses its ability to lock the nut in place. This type of nut should never be used on any exhaust system components or in any place where the nut will be subjected to extreme temperatures.

The ANCHOR NUT (or PLATE NUT) is a self-locking type nut with lugs for fastening it to the structure of the aircraft or engine, usually by riveting. Both types of self-locking nuts mentioned in the preceding paragraphs are available in installations where it is feasible to use an ANCHOR NUT. This type of nut will not be found in general use on the aircraft engine itself, but will be found in and around the cowling.

There are certain precautions that must be taken in the care and use of the self-locking nut. Bolts, studs, and screws with damaged threads or rough ends should not be used, as this will tend to damage the insert and render it ineffective. Do not use self-locking nuts on bolts, studs, or screws that are less than one-fourth inch in diameter and have cotter pin holes. The nuts should not be overtightened. Torque values should be observed at all times, and the bolt must be of sufficient length to protrude through the nut and have at least one full thread visible to the eye.

Bolts

Most bolts used in aircraft structures and engines are either general-purpose, internal-wrenching, or close-tolerance AN (Air Force-Navy), NAS (National Aircraft Standard), or MS (Military Standard) bolts. In many cases the aircraft or engine manufacturer is required to make bolts of different dimensions and greater strength than the standard type of bolt. Such bolts are made for a particular application and it is of extreme importance to use the exact replacement when necessary. If such bolts are not available, but can be manufactured locally, the identical material and heat treatment that are specified in the applicable drawings must be used. Such special bolts are usually identified by an S stamped on the head.

AN bolts come in three head styles–hex-head, clevis, and eyebolt. (See fig. 5-33.) NAS bolts are available in hex-head, internal-wrenching, and countersunk-head styles. MS bolts come in hex-head and internal-wrenching head styles.

Head markings indicate the material of which standard bolts are made and whether or not the bolt is classed as a close-tolerance bolt. (See fig. 5-33.) Additional information, such as bolt diameter, bolt length, and grip length, may be obtained from the bolt part number.

In the bolt part number, AN3DD6A, for example, the AN designates that it is an Air Force-Navy Standard bolt, the 3 indicates the diameter in sixteenths of an inch (3/16), the DD indicates the material is 2024 aluminum alloy, the 6 indicates the grip and length (as taken from special tables), and the A indicates that the shank is not drilled for cotter pin safetying. Absence of the letter A indicates the shank is drilled.

The letter C in place of the DD indicates corrosion-resisting steel, and the absence of a letter indicates, cadmium-plated steel. The letter H preceding the 6 indicates the head is drilled for safetying with wire.

Washers

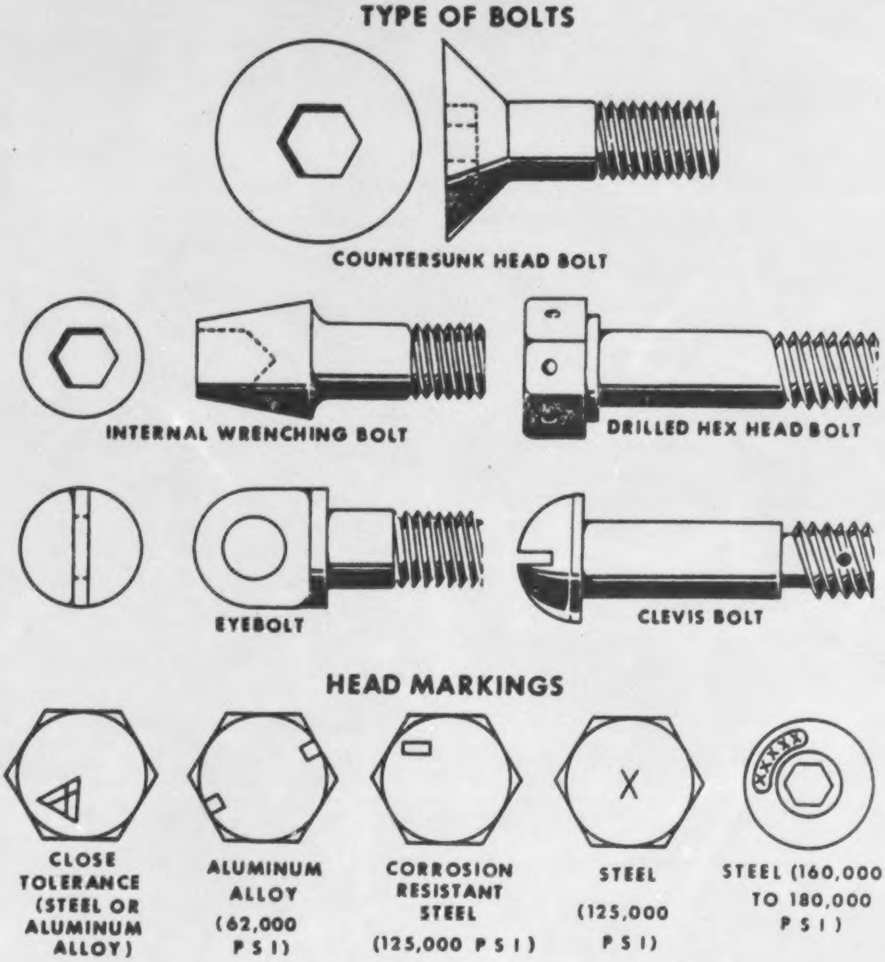
Washers used in aircraft and engines may be grouped into three general classes—PLAIN washers, LOCKWASHERS, and SPECIAL washers. Figure 5-34 shows some of the most commonly used washers.

PLAIN washers are widely used under AN hex nuts to provide a smooth bearing surface to act as a shim in obtaining the correct relationship between the threads of the bolt and the nut, and to adjust the position of castellated nuts with respect to drilled cotter pin holes in the bolts. Plain washers are also used under lockwashers to prevent damage to the surface of soft materials.

LOCKWASHERS are used whenever the self-locking or castellated type nut is not used. Sufficient friction is provided by the spring action of the washer to prevent loosening of the nut from vibration. Lockwashers are not used as part of a fastener for primary or secondary structures or in any place on the engine where vibration may tend to loosen a part.

SPECIAL washers such as ball-socket and seat washers, taper pin washers, and washers for internal-wrenching nuts and bolts are designed for special purposes.

The ball socket and seat washers are used in applications where the bolt may be installed


TYPE OF BOLTS
COUNTERSUNK HEAD BOLT
INTERNAL WRENCHING BOLT
DRILLED HEX HEAD BOLT
EYEBOLT
CLEVIS BOLT
HEAD MARKINGS
CLOSE TOLERANCE (STEEL OR ALUMINUM ALLOY)
ALUMINUM ALLOY (62,000 PSI)
CORROSION RESISTANT STEEL (125,000 PSI)
STEEL (125,000 PSI)
STEEL (160,000 TO 180,000 PSI)

AD.29

Figure 5-33.–Types of bolts and bolt-head markings.

at an angle to the surface or where perfect alignment with the surface is required at all times, such as cylinder holddown bolts and engine mount bolts.

The taper pin washers are used with threaded taper pins, and are installed under the nut to effect adjustment where a plain washer would distort.

Washers that are used for internal-wrenching nuts and bolts are used in conjunction with NAS internal-wrenching bolts. The washer used under the head is countersunk to seat the bolt-head shank radius. A plain type washer is used under the nut.

Installation of Nuts, Bolts and Washers

When any part of an aircraft or engine is about to be installed, it should be ascertained that the correct number and type of nuts, bolts, and washers are used in the installation process. Always examine the markings on the head of the bolt to determine that it is the right type of material to be used for the job at hand.

Be sure that washers are used both under the head of the bolt and under the nut whenever it is specified. A washer guards against damage to the material being bolted and prevents corro-

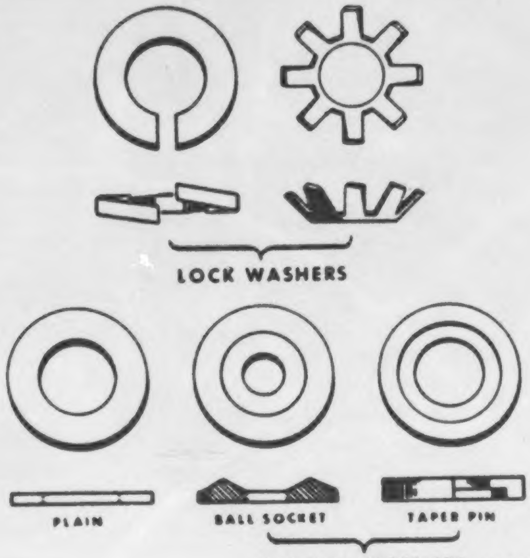


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Figure 5-34.–Various types of washers.

sion of the structural members. An ALUMINUM ALLOY washer should be used under the head and nut of a steel bolt securing ALUMINUM ALLOY or MAGNESIUM ALLOY MEMBERS. Any corrosion that occurs will then attack the washers rather than the members. Steel washers should be used where both the material being fastened and the bolts are made of steel. DO NOT use washers made of ALUMINUM ALLOY or of any other type of soft metal on any part or portion of the exhaust system.

When installing nuts, bolts, and washers, elways be certain to install the bolt with its head in the direction of flight or whenever possible, install it with the head UP. This way, if the nut has been improperly secured or is shaken loose by vibration and falls off, the bolt will remain within the part and continue to retain its holding capability although the nut is missing.

GRIP LENGTH.–Be certain that the grip length of the bolt is correct. The GRIP LENGTH IS THE LENGTH OF THE UNTHREADED PORTION OF THE BOLT SHANK. Generally speaking, the grip length should equal the thickness of the material which is being bolted together. Not more than ONE thread should bear on the material, and the threaded portion of the shank should be showing through the nut. (See fig. 5-35.)

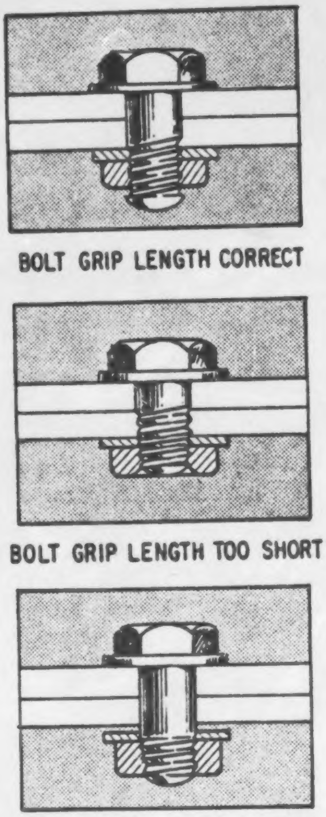

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Figure 5-35.–Correct and incorrect bolt length.

BOLT FIT.–In fitting bolts, all boltholes must present a good mechanical fit. A bolt (or screw) in an oversized or elongated (out-of-round) hole will carry none of its shear load until the parts have yielded or deformed enough to allow the bearing surface of the oversized hole to come in contact with the bolt. Tolerances on drilled holes, unless otherwise specified, as are follows:

Nominal drill diameter	Hole tolerance
0.040 to 0.1285	plus 0.002 minus 0.001
0.136 to 0.228	plus 0.003 minus 0.001

Nominal drill diameter	Hole tolerance
0.234 to 1/2	plus 0.004 minus 0.001
33/64 to 3/4	plus 0.005 minus 0.001
49/64 to 1	plus 0.007 minus 0.001
1 1/64 to 2	plus 0.010 minus 0.001

COTTER PINS

Cotter pins are used to secure bolts, screws, nuts, and pins. Some cotter pins are made of low-carbon steel, while others consist of stainless steel and thus are more resistant to corrosion. In addition, stainless steel cotter pins may be used in locations where nonmagnetic material is required. Regardless of shape or material, all cotter pins are used for the same general purpose–safetying. Figure 5-36 shows three types of cotter pins and how their size is determined.

NOTE: Whenever uneven prong cotter pins are used, the length measurement is to the end of the shortest prong.

SAFETY WIRE

Safety wire comes in many types and sizes. One must first select the correct type and size of wire for the job. Annealed corrosion-resisting wire is used in high-temperature, electrical-equipment, and aircraft-instrument applications. All nuts except the self-locking types must be safetied; the method used depending upon the particular installation. Figure 5-37 illustrates the correct methods of installing safety wire. The following general rules apply to safety wiring:

1. All safety wires must be tight after installation, but not under so much tension that normal handling or vibration will break the wire.
2. The wire must be applied so that all pull exerted by the wire tends to tighten the nut.
3. Twists should be tight and even and the wire between nuts as taut as possible without overtwisting. Wire between nuts should be twisted with the hands. The use of pliers will damage the wire. Pliers may be used only for final end twist prior to cutting off excess wire.

Annealed copper safety wire is used for sealing first aid kits, portable fire exting-

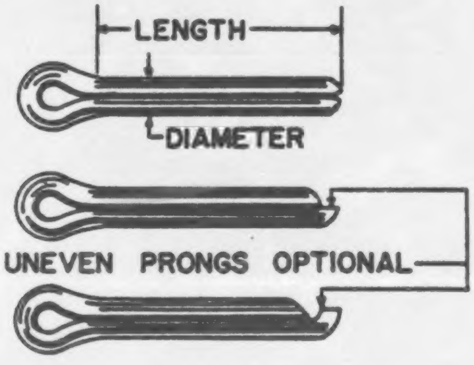

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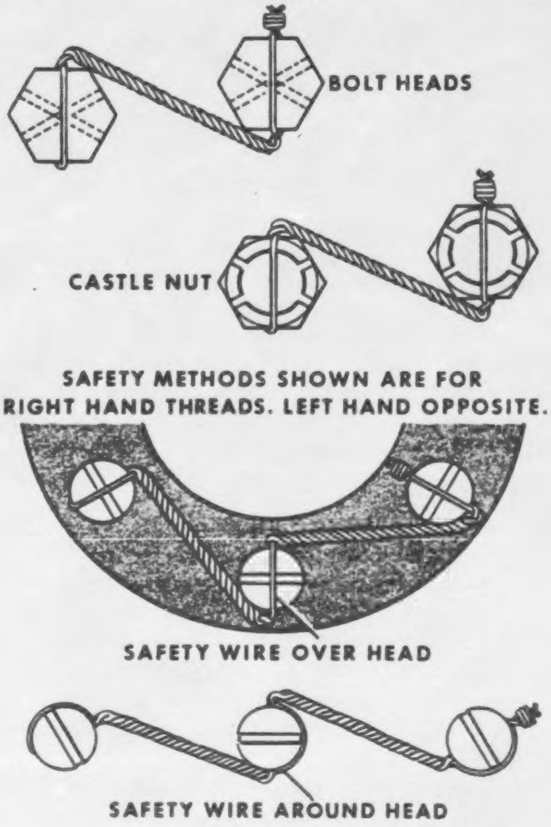
Figure 5-36.–Types of cotter pins.


BOLT HEADS
CASTLE NUT
SAFETY METHODS SHOWN ARE FOR RIGHT HAND THREADS. LEFT HAND OPPOSITE.
SAFETY WIRE OVER HEAD
SAFETY WIRE AROUND HEAD

AM.331
Figure 5-37.–Safety wire installation.

uishers, oxygen regulator emergency valves, and other valves and levers used for emergency operation of aircraft equipment. This wire can be broken by hand in case of an emergency.

SAFETY PRECAUTIONS

Most accidents which occur in noncombat operations can be prevented if the full cooperation of personnel is gained and vigilance is exercised to eliminate unsafe acts. The ADR should diligently inspect his work areas, tools, and equipment to detect potentially hazardous and unsafe conditions and take appropriate corrective action.

Fire hazards present a serious problem. "No Smoking" rules should be strictly enforced. Ground wires should be installed on every aircraft during maintenance to elinate dangerous static electrical buildup. Spilled oil, grease, and chemicals should be wiped up promptly, and all rags used should be disposed of in covered metal containers.

Handtools should be in good shape, of the proper type, and used only for the purpose for which they were designed.

Equipment must be operated only by qualified personnel, and all safety devices and guards must be installed and in good condition. The equipment should also be inspected for broken or damaged components. Check to see that periodic maintenance, servicing, and/or calibration are up to date for those equipments requiring it.

NOTE: The safety precautions presented in the above paragraphs are general in nature and should be observed at all times. For additional information concerning safety precautions for portable tools refer to chapter 14, Department of the Navy Safety Precautions for Shore Activities, NAVSO P-2455.

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CHAPTER 6

RECIPROCATING ENGINE FAMILIARIZATION

The reciprocating engine has been the prime source of power for aircraft since the beginning of aviation. Although the turbojet engine (due to its light weight, ease of maintenance, and reliability) has made steady gains in replacing the reciprocating engine in most naval aircraft, many aircraft still use reciprocating engines. Therefore, the need still exists for well-trained mechanics to maintain these engines.

The fundamental requirements of aircraft reciprocating engines, the theory of operation, and engine construction are discussed in this chapter. In the succeeding chapters the various systems of the reciprocating engine and their interrelationships are discussed separately.

FUNDAMENTAL REQUIREMENTS

All engines must meet certain general requirements of efficiency, economy, and reliability. In addition, the duty for which an aircraft engine is designed imposes other requirements that are almost as important. Besides being economical in fuel consumption, an aircraft engine must be economical in the cost of original procurement and maintenance, and must meet exacting requirements of efficiency and low weight per horsepower. It must be capable of sustained high-power output with no sacrifice in reliability; it must also have the durability to operate for long periods of time between overhauls. It needs to be as compact as possible, yet have easy accessibility for maintenance. It is required to be as vibration free as possible and be able to cover a wide range of power output at various speeds and altitudes.

These requirements dictate the use of ignition systems that will deliver the firing impulse to the spark plugs at the proper time in all kinds of weather and under other adverse conditions. Carburetors are needed that will deliver fuel in the correct proportion to the air ingested to the cylinders regardless of the attitude, altitude, or type of weather in which the engine is operated. The engine needs a type of oil system that delivers oil under the proper pressure to all of the operating parts of the engine at all times it is running. And, it must have a system of dampening units to dampen out the vibrations of the engine that are developed whenever the engine is operating.

All of the above requirements dictate the use of dual ignition, dry sump lubrication in large engines, special carburetor designs, vibration dampening devices, special engine mounts, and many other special features, all of which are relatively less important in powerplants for marine and automobile use.

EFFICIENCY

The reciprocating aircraft engine must have high thermal and mechanical efficiency. Thermal efficiency is the ratio between the number of heat units in the fuel that are converted into useful power at the propeller shaft and the total number of heat units in the fuel that are consumed. The mechanical efficiency is measured by the ratio of the shaft output or brake horsepower to the indicated horsepower developed in the cylinders.

It includes power losses due to friction and other sources in the engine and its accessories. It is obvious then, that whenever the heat and power losses of the engine can be reduced, its efficiency can be increased. The efficiency of

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the engine can also be increased in other ways and these are seen in the following paragraphs.

ECONOMY

Fuel economy is practically another way of saying high thermal efficiency, which was defined in the preceding paragraph. In the early aircraft engines, fuel economy was not too important as most flights were of short duration and military loads were small. But, since the development of the high compression engine and the increased cost of modern day fuels, economy of operation has become an item of prime consideration.

RELIABILITY

The reliability of aircraft engines is of prime importance. Engine failure of a carrier based aircraft not only reduces the fighting effectiveness of the carrier but also results in the loss of material and in many cases, highly trained pilots and crewmen if the aircraft is lost at sea. The engine manufacturer insures the reliability of his product by spending thousands of dollars and manhours in design, research, and testing. Close control of every manufacturing and assembly procedure is maintained, and each engine is thoroughly tested before it leaves the factory. An additional insurance factor is that the Navy requires that every engine coming from the factory must pass a Navy acceptance test before it is finally accepted.

Reliability is thus built into the engine by the manufacturer, but the continued reliability of the engine is determined by the maintenance, overhaul, and flying personnel. Careful maintenance and overhaul methods, thorough periodic inspections, and strict observation of the operating limits established by the engine manufacturer and the Navy will make engine failure a rare occurrence.

WEIGHT

If the weight of an engine per brake horsepower (called the specific weight of the engine) is decreased, the useful load that an aircraft can carry and the performance of the aircraft itself obviously are increased. Every excess pound of weight carried by an aircraft reduces its performance. Tremendous gains in reducing the weight of the aircraft engine through improvement in design and metallurgy have resulted in engines now producing approximately 1 horsepower for each pound of weight.

SUSTAINED HIGH-POWER OUTPUT

Unlike the automobile engine, the aircraft engine must operate at a relatively high percentage of its maximum power output throughout its service life. The aircraft engine is at full power output whenever a takeoff is made. It may or may not hold this power for periods of time up to the limits that have been set by the manufacturer. Very seldom is maximum power held on the engine for more than 2 minutes and usually not that long. Within a few seconds after lift-off, the power is reduced to a power that is used for climbing and which can be maintained for longer periods of time. After climbout to cruising altitude has been accomplished, the power of the engine(s) is further reduced to a cruise power which can be maintained for the duration of the flight.

DURABILITY

In a well-designed aircraft engine, the cost of operation is reduced by the durability of the engine, which materially extends the periods between necessary overhauls. Early aircraft engines required overhauling after comparatively few hours of operation. Today, for certain types of engines used in naval aviation, operation for periods in excess of 1,500 hours between overhauls is authorized. Engine designers have devoted much thought and consideration to the requirement of durability; metallurgists also have made major contributions to increased durability by the development of stronger and tougher metals. The durability built into the engine must be safeguarded by strict adherence to good maintenance and operating procedures.

ACCESSIBILITY

For purposes of inspection, repair, or replacement of parts and making adjustments to various units of the engine, it is necessary that all sections of the engine and its accessories should be as accessible as possible.

PARTS INTERCHANGEABILITY

The various parts of an aircraft engine are made with such precision that it is possible to exchange parts without the necessity of extensive hand fitting. The interchangeability of parts between engine models of like horsepower simplifies the stockkeeping problems of the aviation supply system and reduces the number of spare parts required for emergency situations.

COMPACTNESS

In order to effect proper streamlining and balancing of an aircraft, the shape and size of the engine must be as compact as possible. In single-engine aircraft, the shape and size of the engine also affect the view of the pilot, making a smaller engine better from this standpoint in addition to reducing the drag created by a large frontal area.

Weight limitations, naturally, are closely related to the compactness requirement. The more difficult it becomes to keep the specific weight within the allowable limits. The radial engine, due to its compact arrangement, has the advantage over the inline type in keeping its weight within allowable limits in proportion to the horsepower developed. To enable the inline engine to develop power comparable to the radial engine, its weight and length would have to be increased proportionately.

OPERATING FLEXIBILITY

Operating flexibility is the ability of an engine to run smoothly and give desired performance at all speeds from the idling range to maximum power allowable. In addition to the requirement of unfailing reliability, the engine may be operated in widely varying positions and in extreme weather conditions. Driving the modern day propeller has put a demand on the engine to produce a wide range of operating speeds that the engine of yesterday did not have to meet.

THEORY OF OPERATION

Before discussing the theory of operation of the internal-combustion reciprocating engine, it must be clear how it derives its name.

In the first place, internal combustion is the process by which a mixture of air and fuel is burned in a chamber from which power may be taken directly. The word engine means a machine in which heat energy released by the process of combustion is converted into mechanical energy. Reciprocating means motion back and forth, in the case of engines, the motion of the piston within the cylinder. Therefore, in the reciprocating engine, gasoline is vaporized and mixed with air, is then forced or drawn into a cylinder, compressed by a piston, and then ignited by an electric spark. The conversion of the resultant heat energy into mechanical energy and then into work is accomplished in the cylinder. (See fig. 6-1.).

The operating cycle of internal-combustion reciprocating engine may be defined as the series of events required to induce, compress, ignite, burn, and expand the air/fuel charge in the cylinder, and to scavenge or exhaust the products of the combustion process.

When the compressed mixture is ignited, the resultant gases of combustion expand very

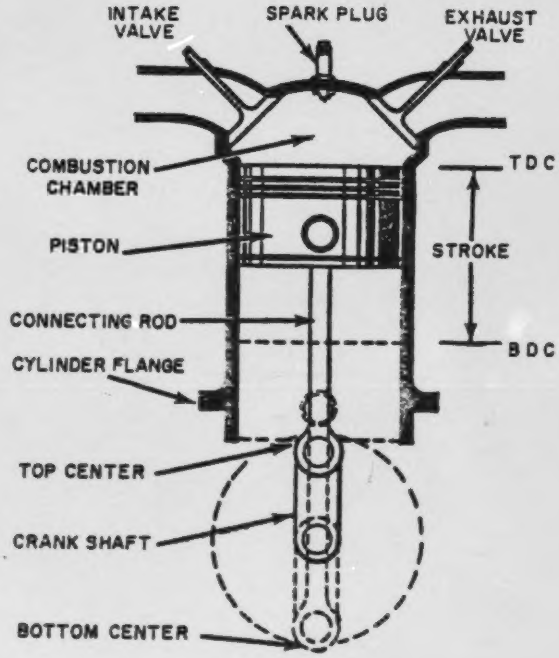

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Figure 6-1.–Reciprocating engine cylinder.

rapidly and force the piston to move away from the cylinder head. This downward motion of the piston, acting on the crankshaft through the connecting rod, is converted to a circular or rotary motion by the crankshaft, and thus through a reduction gearing system drives the propeller shaft.

A valve in the top or head of the cylinder opens to allow the burned gases to escape, and the momentum of the crankshaft and the propeller forces the piston back up in the cylinder where it is ready for the next event in the cycle. Another valve in the cylinder head then opens to let in a fresh charge of the air/fuel mixture.

The valve allowing for the escape of the burning exhaust gases is called the EXHAUST VALVE, and the valve which lets in the fresh charge of the air/fuel mixture is called the INTAKE VALVE. These valves are opened and closed mechanically at the proper times by the valve operating mechanism.

Other terms used in describing engine operation are as follows:

1. BORE and STROKE. The BORE is the internal diameter of the cylinder. The STROKE is the distance that the piston travels from the top to the bottom, or from the bottom to the top, of the cylinder. For each revolution of the crankshaft there are two strokes of the piston, one up and one down.

2. TOP DEAD CENTER (TDC). Top dead center is the position that a piston assumes when it reaches its maximum distance from the centerline of the crankshaft. This position may also be referred to as "the top of the stroke."

3. BOTTOM DEAD CENTER (BDC). Bottom dead center is the position that the piston assumes when it reaches its minimum distance from the centerline of the crankshaft. This position is also known as "the bottom of the stroke," and it is at the opposite end of the cylinder from the top dead center position.

4. COMPRESSION RATIO. The volume of the space in a cylinder above the piston at top dead center is the clearance volume. The ratio between the total volume of the cylinder with the piston at bottom dead center, to the clearance volume, is called the compression ratio. This is expressed 7:1, 9:1, etc.

There are two operating cycles in general use–the two-stroke cycle and the four-stroke cycle. The two-stroke has disappeared from naval aviation. It was used largely in powering auxiliary power units to furnish power for starting aircraft and to supply power to the aircraft for checking electrical units aboard. As the name implies, two-stroke cycle engines require only one up and one down stroke of the piston to complete the required series of events in the cylinder. Thus the engine completes the operating cycle in one revolution of the crankshaft as shown in figure 6-2.

All aircraft reciprocating engines in present use in naval aviation operate on the four-stroke cycle, sometimes called the OTTO CYCLE after its originator, a German physicist.

The four-stroke cycle engine has many advantages for use in aircraft. One is that this type of engine lends itself readily to high performance through supercharging.

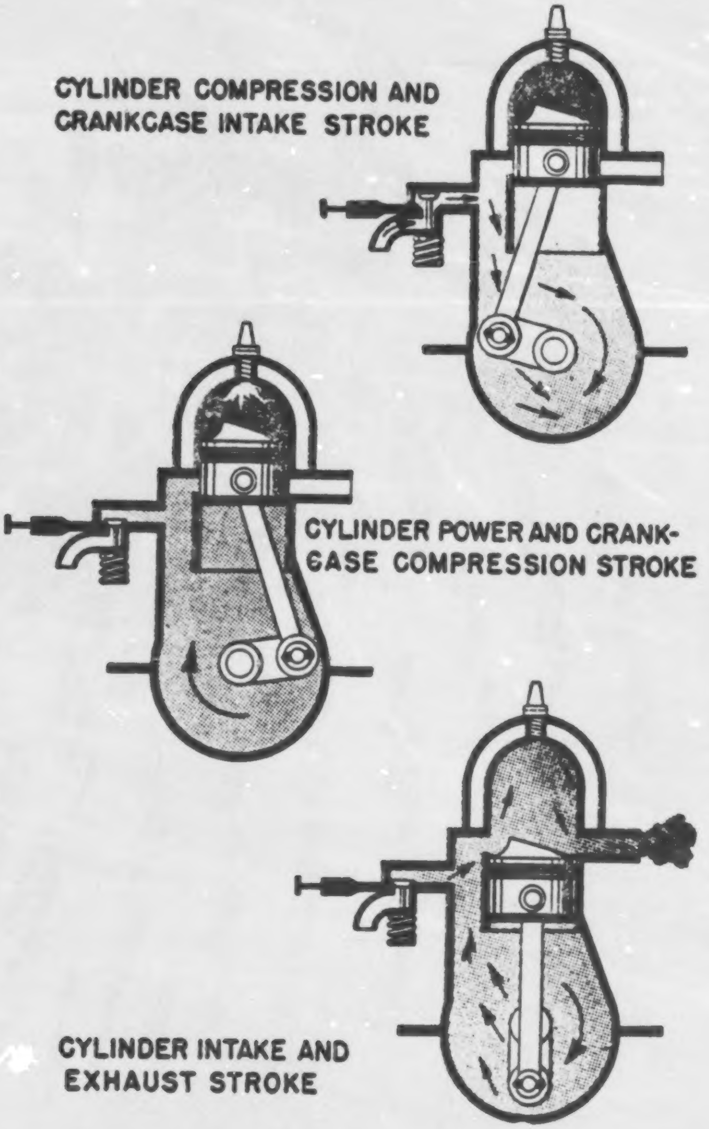
In this type of engine, four strokes are required to complete the required series of events or operating cycle of each cylinder, as shown in figure 6-3. Two complete revolutions of the crankshaft are required for the four strokes; thus, each cylinder in an engine of this type fires once in every two revolutions of the crankshaft.

FOUR-STROKE CYCLE ENGINE OPERATION

An engine cycle is the series of operations or events which an internal combustion engine must perform to operate continuously and deliver power. These events are timed (made to occur in a certain sequence) by the construction of the engine.

Inside a 9-cylinder four-cycle engine operating at 2,000 revolutions per minute (RPM), a series of events is being repeated very rapidly. In 1 minute, 9 pistons start and stop 4,000 times; 18,000 sparks jump across the points of 18 spark plugs; 9 intake and 9 exhaust valves open and close 1,000 times. Despite this apparent complexity of operation, only 5 different events (induction, compression, ignition, expansion, and exhaust) are taking place, but each cylinder is repeating these events very rapidly. These 5 events comprise the cycle of operation. These cycles (fig. 6-3)are discussed in the following paragraphs.

NOTE: In the following discussion of the four-stroke cycle engine operation, it should be


CYLINDER COMPRESSION AND CRANKCASE INTAKE STROKE
CYLINDER POWER AND CRANKCASE COMPRESSION STROKE
CYLINDER INTAKE AND EXHAUST STROKE

AD.31

Figure 6-2.–Two-stroke cycle.

realized that the timing of the ignition and the valve events will vary considerably in different engines. Many factors influence the timing of a specific engine, and it is most important that the engine manufacturer's recommendations in this respect be followed by service personnel in maintenance and overhaul. The timing of the valve and ignition events is always specified in degrees of crankshaft travel.

It can be noted in the following paragraphs that the timing of each event is specified in terms of degrees of crankshaft travel on the stroke during which the event occurs. It should be remembered that a certain amount of crankshaft travel is required to open a valve fully; therefore, the specified timing represents the start of opening rather than the full-open position of the valve.

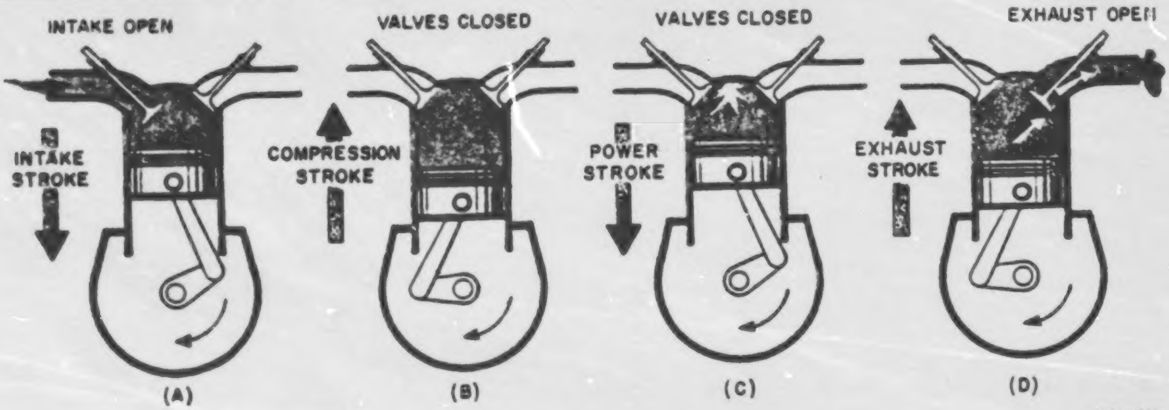


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Figure 6-3.–Four-stroke cycle.

Intake Stroke

During the intake stroke, the piston is pulled downward in the cylinder by the rotation of the crankshaft. This reduces the pressure in the cylinder and causes air under atmospheric pressure to flow through the carburetor, which meters the correct amount of fuel. The air/fuel mixture is compressed by the impeller and then passes through the intake pipes and intake valves into the cylinders. The quantity or weight of the air/fuel charge depends upon the degree of throttle opening.

The intake valve is opened considerably before the piston reaches top dead center on the exhaust stroke, in order to induce a greater quantity of the air/fuel charge into the cylinder and thus increase the horsepower. The distance the valve may be opened before top dead center, however, is limited by several factors, such as the possibility that hot gases remaining in the cylinder from the previous cycle may flash back into the intake pipe and the induction system.

In all high-power aircraft engines, both the intake and the exhaust valves are off the valve seats at top dead center at the start of the intake stroke. As mentioned above, the intake valve opens before top dead center on the exhaust stroke (valve lead), and the closing of the exhaust valve is delayed considerably after the piston has passed top dead center and has started the intake stroke (valve lag). This timing is called VALVE OVERLAP and is designed to aid in cooling the cylinder internally by circulating the cool incoming air/fuel mixture, to increase the amount of the air/fuel mixture induced into the cylinder, and to aid in scavenging the products of combustion.

The intake valve is timed to close about 50° to 75° past bottom dead center on the compression stroke, depending upon the specific engine, to allow the momentum of the incoming gases to charge the cylinder more completely. Because of the comparatively large volume of the cylinder above the piston when the piston is near bottom dead center, the slight upward travel of the piston during this time does not have a great effect on the incoming flow of gases. This late timing can be carried too far because the gases may be forced back through the intake valve and defeat the purpose of the late closing.

Compression Stroke

After the intake valve is closed, the continued upward travel of the piston compresses the air/fuel mixture in order to obtain the desired burning and expansion characteristics.

The charge is fired by means of an electric spark as the piston approaches top dead center. The time of ignition will vary from 20° to 35° before top dead center, depending upon the requirements of the specific engine, in order to insure complete combustion of the charge by the time the piston is slightly past the top dead center position.

Many factors affect ignition timing, and the engine manufacturer has expended considerable time in research and testing to determine the best setting. All engines incorporate devices for adjusting the ignition timing, and it is most important that the ignition system be timed according to the engine manufacturer's recommendations.

Power Stroke

As the piston moves through the top dead center position at the end of the compression stroke and starts downward on the power stroke, it is pushed by the rapid expansion of the burning gases in the cylinder head with a force that can be greater than 15 tons at the maximum power output of the engine. The temperature of these burning gases may be between 3,000° and 4,000°F.

As the piston is forced downward during the power stroke by the pressure of the burning gases exerted upon it, the downward movement of the articulating (connecting) rod is changed to rotary movement by the crankshaft. Then the movement is transmitted to the propeller shaft to drive the propeller. As the burning gases are expanded, the temperature drops to within safe limits before the exhaust gases pass out through the exhaust valve.

The timing of the exhaust valve is determined by, among other considerations, the desirability of using as much of the expansive force as possible and of scavenging the cylinder as completely and rapidly as possible. The valve is opened considerably before bottom dead center on the power stroke (on some engines at 50° to 75° before bottom dead center) while there is still some pressure in the cylinder. This timing is used so that the pressure can force the gases out of the exhaust port as soon as possible. This process frees the cylinder of waste heat after the desired expansion has been obtained and avoids overheating the cylinder and the piston. Thorough scavenging is very important, because any exhaust products remaining in the cylinder will dilute the incoming air/fuel charge at the start of the next cycle.

Exhaust Stroke

As the piston travels through bottom dead center at the completion of the power stroke and starts upward on the exhaust stroke, it will begin to push the burned exhaust gases out the exhaust port. The speed of the exhaust gases leaving the cylinder creates a low pressure in the cylinder. This low or reduced pressure is used to speed the flow of the fresh air/fuel charge into the cylinder as the intake valve is beginning to open. The intake valve opening is timed to occur at 8° to 55° before top dead center on the exhaust stroke on various engines.

NOTE: The preceding description of the operating cycles and of the four-stroke cycle operation is of a general nature and should not be used for any specific model engine. For specific instructions always refer to the applicable publications for each individual engine.

HORSEPOWER

The common unit of mechanical power is the horsepower (hp). Late in the 18th century, James Watt, the inventor of the steam engine, found that an English workhorse could work at the rate of 550 ft-lb per second, or 33,000 ft-lb per minute, for a reasonable length of time. From his observations came the HORSEPOWER, which is the standard unit of power in the English system of measurement.

As stated above, work is the product of force and distance, and power is work per unit of time. Consequently, if a 33,000-pound weight is lifted through a vertical distance of 1 foot in 1 minute, the power expended is 33,000 ft-lb per minute, or exactly 1 horsepower.

Work is performed not only when a force is applied for lifting; force may be applied in any direction. If a 100-pound weight is dragged along the ground, a force is still being applied to perform work, although the direction of the resulting motion is approximately horizontal. The amount of this force would depend upon the roughness of the ground.

If the weight were attached to a spring scale graduated in pounds, then dragged by pulling on the scale handle, the amount of force required could be measured. Assume that the force required is 90 pounds, and the 100-pound weight is dragged 660 feet in 2 minutes. The amount of work performed in the 2 minutes will be 59,400 ft-lb, or 29,700 ft-lb per minute. Since 1 horsepower is 33,000 ft-lb per minute, the horsepower expended in this case will be 29,700 divided by 33,000, or 0.9 horsepower.

Indicated Horsepower

The INDICATED HORSEPOWER (ihp) produced by an engine is the horsepower calculated from the indicated mean effective pressure and the other factors which affect the power output of an engine. Indicated horsepower may be said to be the power developed in the combustion chambers without reference to friction losses within the engine. The ihp for a four-cycle engine can be calculated from the following formula, in which the letter symbols in the numerator are arranged to spell the word "plank" to assist in memorizing the formula:

$$\text{ihp} = \frac{PLANK}{33{,}000}$$

where:

P = Indicated mean effective pressure (imep) in pounds per square inch.
L = Length of the stroke in feet or in fractions of a foot.
A = Area of the piston head or cross sectional area of the cylinder, in square inches.
N = Number of power strokes per minute, $\frac{\text{rpm}}{2}$.
K = Number of cylinders.

In the formula above, the area of the piston times the imep gives the force acting on the piston in pounds. This force multiplied by the length of the stroke in feet gives the WORK performed in one power stroke, which, multiplied by the number of power strokes per minute, gives the number of ft-lb per minute of work produced by one cylinder. Multiplying this result by the number of cylinders in the engine gives the amount of work performed, in ft-lb, by the engine. Since horsepower is defined as work done at the rate of 33,000 ft-lb per minute, the total number of ft-lb of work performed by the engine is divided by 33,000 to find the indicated horsepower.

Friction Horsepower

Friction horsepower is the indicated horsepower minus brake horsepower. It is the horsepower used by an engine in overcoming the friction of moving parts, drawing in fuel, expelling exhaust, driving oil and fuel pumps, and the like. On modern aircraft engines this power loss through friction may be as high as 10 to 15 percent of the indicated horsepower.

Brake Horsepower

The actual horsepower that is delivered to the propeller shaft is called brake horsepower. It is the indicated horsepower minus the friction horsepower and is that part of the total horsepower developed that can actually be used to do work.

Thrust Horsepower

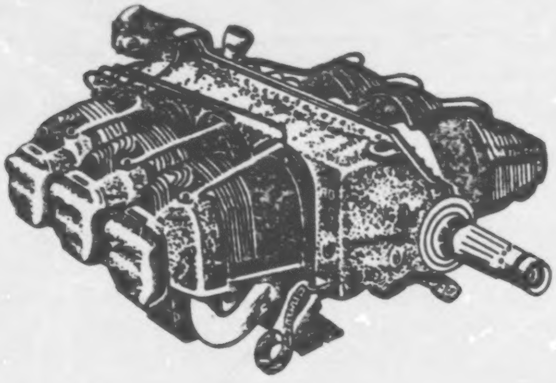
Thrust horsepower can be considered as the end result of the engine and the propeller working together. If a propeller could be designed to be 100 percent efficient, the thrust horsepower and the brake horsepower would be the same. However, the efficiency of the propeller varies with the engine speed, attitude, altitude, temperature, airspeed, and while taxiing; thus the ratio of the thrust horsepower and the brake horsepower delivered to the propeller shaft will never be equal. For example, if an engine develops 1,000 brake horsepower and is used with a propeller having 85 percent efficiency, the thrust horsepower of that engine-propeller combination is 85 percent of 1,000, or 850 thrust horsepower. Of the four types of horsepower discussed, it is the thrust horsepower that determines the performance of the engine-propeller combination.

ENGINE TYPES AND DESIGNATIONS

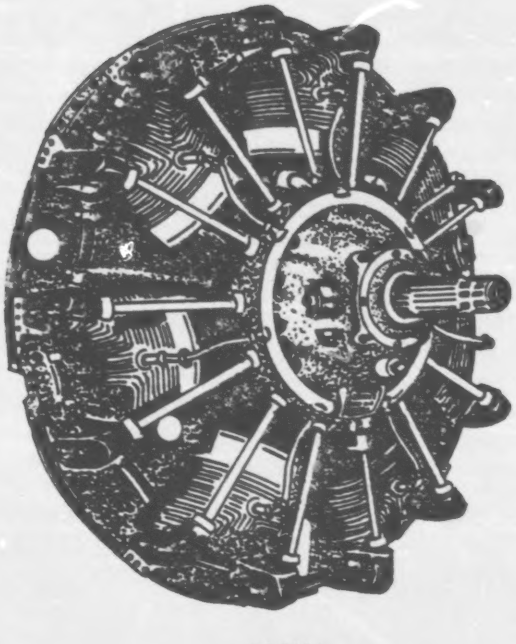
Although aircraft engines of many different designs have been constructed and used in naval aircraft, the only types of engines in use today are the inline and radial. The difference in these two types of engines, as discussed in the following paragraphs, is the types of crankshaft and cylinder arrangement. (See fig. 6-4.)

INLINE

Inline engines have the cylinders arranged in one or more straight lines, parallel to the crankshaft. Inline engines may be vertical,



OPPOSED



RADIAL

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Figure 6-4.–Types of reciprocating engines.

opposed, or V; these type names are derived from the cylinder arrangement. These engines can be air cooled or liquid cooled. The only type of inline engine used in naval aircraft is the air-cooled opposed type.

NOTE: Although a limited number of opposed type inline engines are in use in the Navy, the radial is considered the basic aircraft engine and is used for discussion in this training manual.

RADIAL

Radial engines are built with the cylinders arranged around the crankcase. The 18-cylinder radial engine shown in figure 6-4 illustrates how the cylinders radiate from the crankcase similar to the spokes in a wheel. Modern radial engines have the cylinders arranged in one or two rows and are accordingly termed single-row and double-row. Present single-row engines have 7 or 9 cylinders, while the double-row engines have 14 cylinders in two rows of 7, or 18 cylinders in two rows of 9. The largest radial engine used by the Navy was the R-4360 which had 28 cylinders composed of four rows of 7 cylinders each.

DESIGNATIONS

A system of engine designation has been developed and is currently being used by the Navy and Air Force. It utilizes standard symbols to represent the type and model of the various engines currently being used in military aircraft and missiles.

The standard designation system classifies aircraft reciprocating engines according to cylinder arrangement (O–opposing and R–radial) and the size of the engine in terms of total piston displacement to the nearest 5 cubic inches (area of the piston head in square inches times the length of the stroke in inches times the number of cylinders). In addition, a model number is assigned to each new model of the basic engine.

Figure 6-5 illustrates the designation symbols for a widely used radial engine and should be referred to during the following discussion.

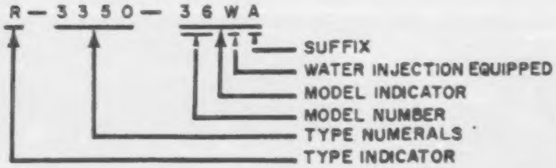

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Figure 6-5.–Reciprocating engine designation symbols.

1. Type indicator. The first part of the designation consists of a letter indicating the type of engine. (R–radial.)

2. Type numerals. The type numerals consist of a dash and a number representing piston displacement to the nearest 5 cubic inches. (3,350-cubic inches displacement.)

3. Model indicator. The model indicator consists of a dash and a model number or a dash and a model number with a suffix letter.

a. Model number. The model number is a numeral(s) which is assigned to identify a specific configuration within the engine type. Air Force model numbers for each type of engine begin with -1 and continue with consecutive ODD numbers. Navy model numbers begin with -2 and continue with consecutive EVEN numbers. (36–Navy developed.)

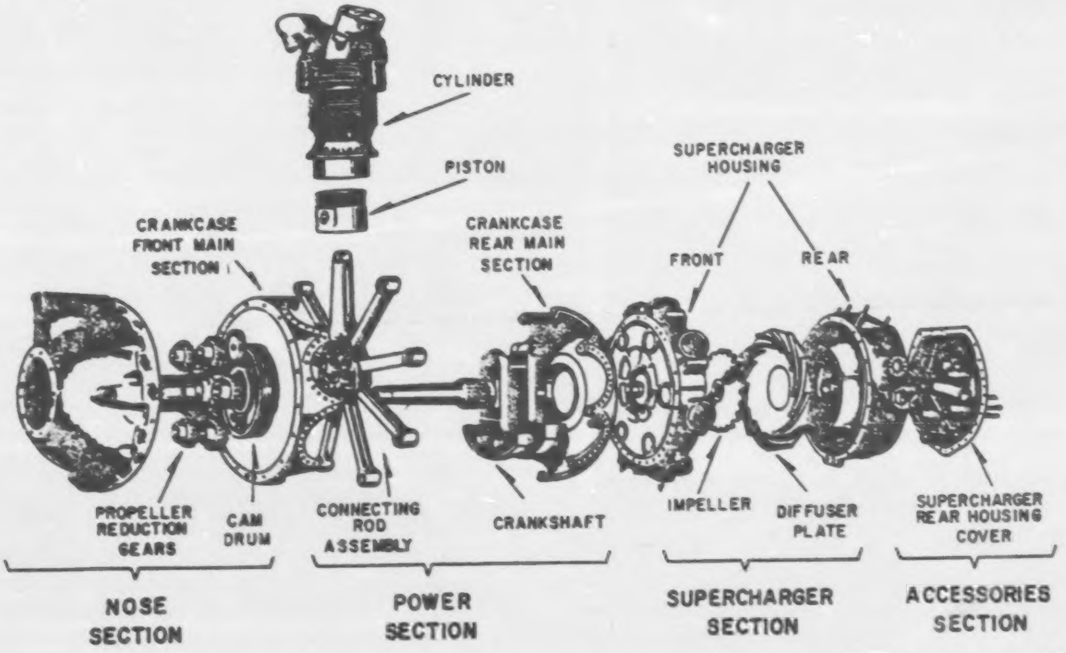
NOTE: If the Air Force or Navy procures an engine model originally developed for the other service, the type number does not change.

b. Suffix letter(s). The suffix letter indicates a minor design change which affects performance, flight safety, installation, or interchangeability of the complete engine in a specific airplane. In general, suffix letters are added consecutively starting with the letters A, B, C, etc., except for the letter "W" which is reserved to indicate engines equipped with water injection. When so used, the suffix letter "W" always precedes any other suffix letter included in the model indicator. (W–water injection equipped.) (A–minor design change.)

RECIPROCATING ENGINE CONSTRUCTION

For a thorough knowledge of aircraft reciprocating engines, it is essential that the Aviation Machinist's Mate R know how they are constructed. First, he should learn that the engine is constructed in several distinct sections.

Engine sections, as illustrated in figure 6-6, serve as housings for the crankshaft, reduction gears, and drive assemblies of the engine. They afford rigidity to the entire engine structure and serve as the base or bed on which the engine is built.


CYLINDER
PISTON
CRANKCASE FRONT MAIN SECTION
CRANKCASE REAR MAIN SECTION
SUPERCHARGER HOUSING
FRONT
REAR
PROPELLER REDUCTION GEARS
CAM DRUM
CONNECTING ROD ASSEMBLY
CRANKSHAFT
IMPELLER
DIFFUSER PLATE
SUPERCHARGER REAR HOUSING COVER
NOSE SECTION
POWER SECTION
SUPERCHARGER SECTION
ACCESSORIES SECTION

AD.35

Figure 6-6.–Engine sections.

Engine sections support the cylinders and the crankshaft, and provide the means of attaching the engine to the engine mount and to the aircraft structure.

CRANKCASE SECTIONS

The engine shown in figure 6-6 is a single-row, nine-cylinder, radial engine of relatively simple construction, having a one-piece nose and a two-section main crankcase. The larger twin-row engines are of slightly more complex construction. For example, the crankcase of the Wright R-3350-32W engine is composed of the crankcase front section, four crankcase main sections (the front main, the front center, the rear center, and the rear main sections) the rear cam and tappet housing, the supercharger front housing, the supercharger rear housing, and the supercharger rear housing cover. Pratt and Whitney engines of comparable size incorporate the same basic sections, although the construction and the nomenclature differ considerably. An exploded view of the R-3350 engine is shown in figure 6-7.

Front Section

The crankcase front section supports the propeller shaft bearings, thrust nut, propeller reduction gearing, propeller governor, distributors, front oil sump and scavenge pump, torque cell, torquemeter boost pump, and the ignition harness. The front cam and tappet assembly, which opens and closes the valves in the front row of cylinders, is also located in this section.

Crankcase Main Sections

The crankcase main sections (the front main, front center, rear center, and the rear main) house the main bearings, which support the crankshaft. This portion of the engine is often referred to as the power section, for it is here that the reciprocating motion of the

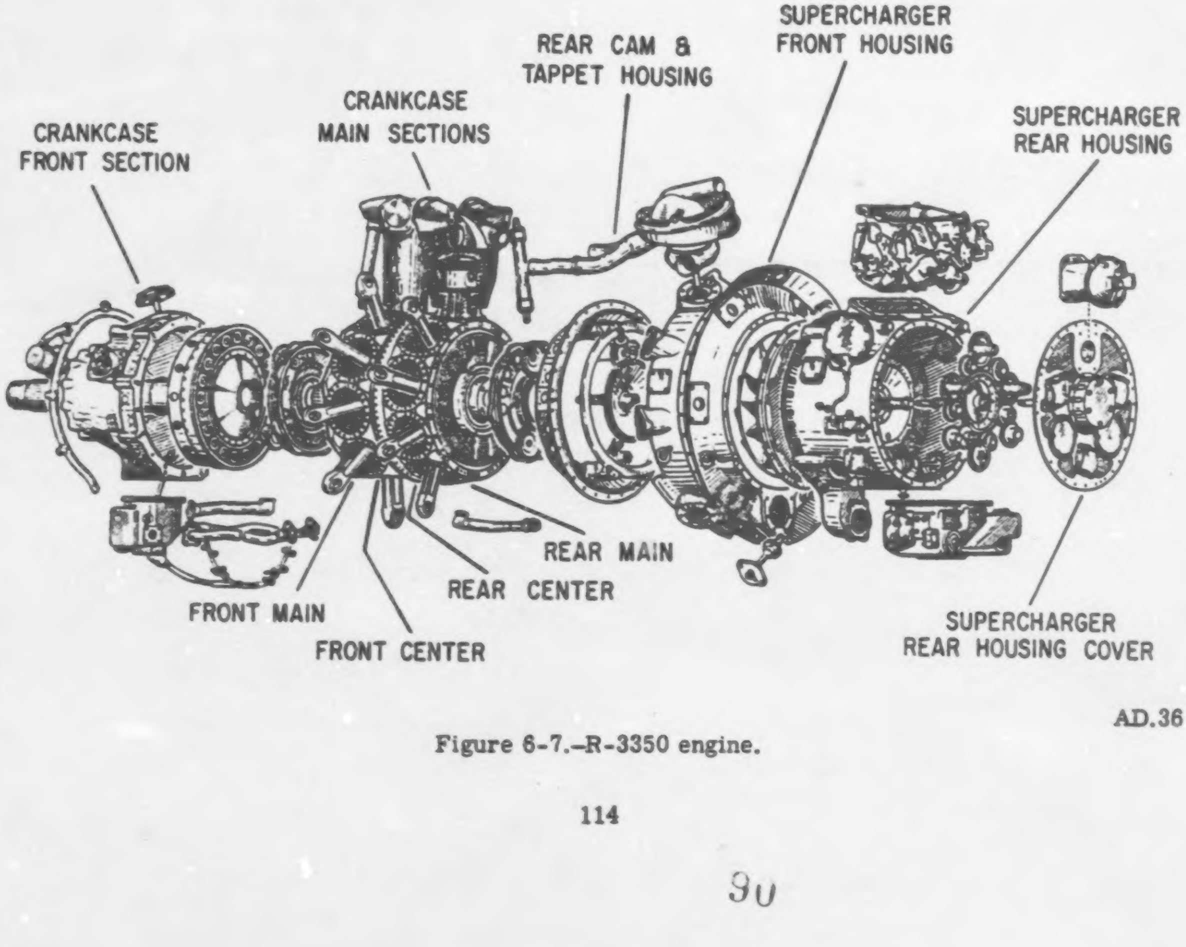

SUPERCHARGER FRONT HOUSING
REAR CAM & TAPPET HOUSING
CRANKCASE MAIN SECTIONS
CRANKCASE FRONT SECTION
SUPERCHARGER REAR HOUSING
REAR MAIN
REAR CENTER
FRONT MAIN
FRONT CENTER
SUPERCHARGER REAR HOUSING COVER
AD.36

Figure 6-7.–R-3350 engine.

engine is converted to the rotary motion of the crankshaft. The cylinders are mounted on these sections.

Rear Cam and Tappet Housing

The rear cam and tappet assembly, which actuates the valves of the rear row of cylinders, is housed in this section of the crankcase.

Supercharger Front Housing

The supercharger front housing provides outlets from the supercharger, through which the air/fuel mixture is directed (through the intake pipes) to the cylinders. Mounting pads are provided for attaching the engine to the engine mount. The power recovery turbines are mounted on the front supercharger housing.

Supercharger Rear Housing

Together with the supercharger front housing, the supercharger rear housing contains the supercharger and the supercharger drive mechanism. It also provides a mounting place for the carburetor (or master control), direct fuel injection pumps, the engine-driven fuel pump, the tachometer generator, the synchronizing generator for the engine analyzer, and the rear oil sump. The supercharger front housing and the supercharger rear housing are shown in figure 6-8.

CRANKSHAFT

The crankshaft of the engine receives the power developed in the cylinders and delivers it to the propeller. In other words, it converts the power strokes of the pistons into the rotary motion which turns the propeller.

Crankshafts are termed single-throw and two-throw and are used in single-row and twin-row radial engines respectively. The terms "single piece" and "built-up" may also be applied to crankshafts according to the method of construction employed.

Crankshaft Construction

Crankshafts are machined from solid steel forgings of nickel alloy steel. The crankshafts used in single-row and twin-row engines are usually built up from two or three sections. The crankshaft of the R-3350 engine consists of three sections; the crankshaft front, center, and the rear section and permits the use of solid master rods. Other engines may use a single piece crankshaft in which all the journals and crankpins are machined as a single unit. It is necessary to use a split type master rod with such units.

Two general methods are used in the construction of built-up crankshafts. The crankshaft shown in figure 6-9 employs the split-clamp method; other crankshafts use the split-spline method.

In all crankshafts used in naval aircraft engines, the journals and crankpins are of hollow construction to allow for the minimum weight with the maximum bearing surface.

Crankshaft Balancing

The counterweights shown in the crankshaft illustration serve two functions. First, the counterweights balance the rotating and reciprocating masses of the crankpin and the connecting rods. Secondly, in all modern aircraft engines the counterweights serve to dampen the separate power impulses and thus dampen the torsional or twisting vibrations imposed on the crankshaft insuring the even flow of power to the propeller shaft. This latter operation is performed by suspending the counterweights from the crankcheeks. (See fig. 6-9.) The slight movement allowed the counterweights tends to offset the power impulses and provides for smoother operation.

ARTICULATING RODS

In a radial engine the piston in one cylinder in each row is connected to the crankshaft by a master rod. All other pistons in the row are connected to the master rod by an articulating rod. In the case of the R-3350 engine, which has 2 rows of cylinders, there are 2 master rods and 16 articulating rods. At engine assembly, the entire master and articulating rod assembly is built up and then installed on the crankpin as a unit. A typical radial engine master rod arrangement is shown in figure 6-10.

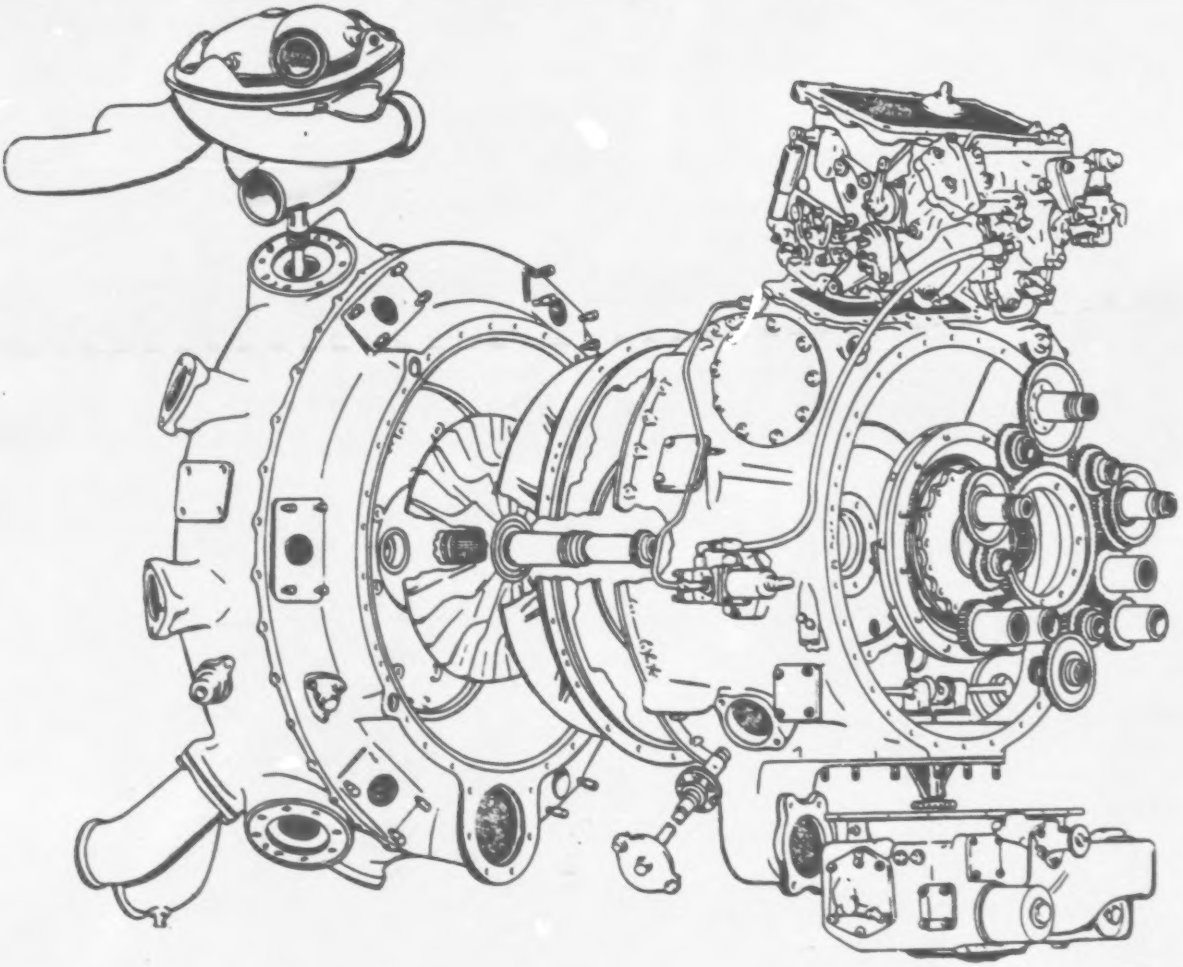


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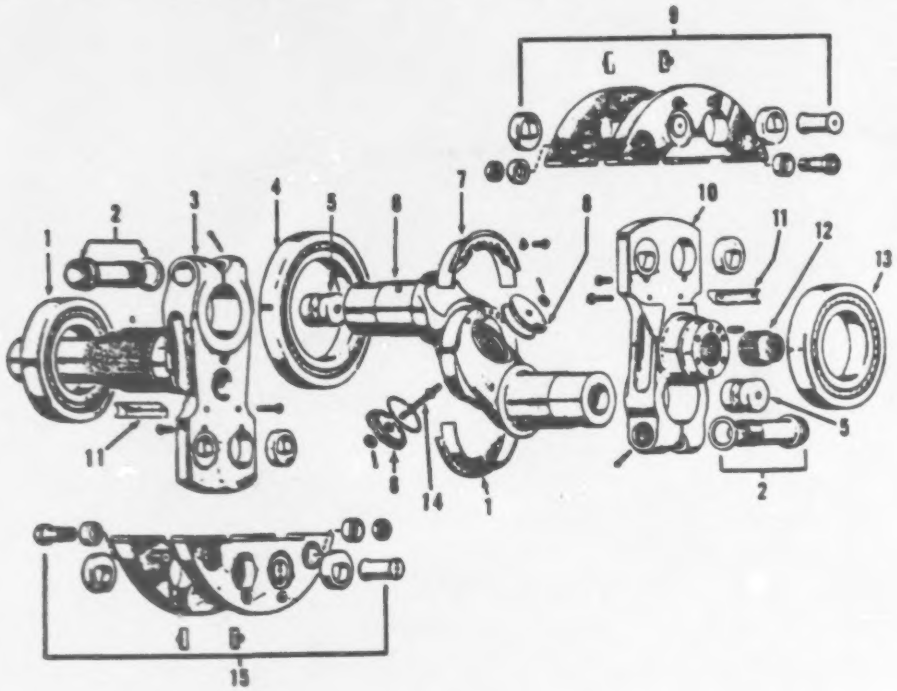
Figure 6-8.–Supercharger front and rear housings.

The articulating rods are constructed of forged steel alloy in either the I- or H-shape, denoting the cross sectional shape. Bronze bushings are pressed into the bores in each end of the rod to provide knuckle pin and piston pin bearings. In the R-3350 engine, the knuckle pin bushing is lined with lead-tin on the inner diameter.

NOTE: In the inline engine, the pistons are connected directly to the crankshaft by connecting rods. The typical inline engine will have connecting rods that have been constructed in the same manner as the articulating rods. However, the crankshaft end will be larger and will have a replaceable bearing insert.

MASTER ROD(S)

The master rod serves as the connecting link between the piston pin and the crankpin; it also provides for the attachment of the articulating rods. The master rod is usually shaped like a banjo. The crankpin end or the "big end" contains the crankpin or master rod bearing; flanges around the big end provide for the attachment of the articulating rods. The articulating rods are attached to the master rod by the knuckle pins, which are pressed into holes in the master rod flanges at assembly. A plain bearing, usually called a piston pin bushing, is in-



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1. Front main bearing.
2. Crankcheek clamp, screw, and washer.
3. Crankshaft front section.
4. Center main bearing.
5. Crankpin plug.
6. Crankshaft center section.
7. Center bearing support.
8. Center section oil retainer.
9. Rear counterweight assembly.
10. Crankshaft rear section.
11. Counter weight stop.
12. Accessory drive and starter shaft.
13. Rear main bearing.
14. Oil retainer bolt.
15. Front counterweight assembly.

Figure 6-9.—Two-throw crankshaft (R-3350 engine).

stalled in the piston end of the master rod to receive the piston pin.

The master rod piston is more heavily loaded than the other pistons in the same row because this piston restrains the master rod from turning around the crankpin under power impulses from the other pistons.

When a crankshaft of the split-spline or split-clamp type is employed, a one-piece master rod is used. The master and the articulating rods are assembled and then installed on the crankpin; the crankshaft sections are then joined together. In engines that use the one-piece type of crankshaft, the big end of the master rod is split, as is the crankpin or master rod bearing. The main part of the master rod is installed on the crankpin; then the bearing cap is set in place and bolted to the master rod.

Knuckle Pins

The knuckle pins are of solid construction except for the oil passages drilled in the pins, which lubricate the knuckle pin bushings. These

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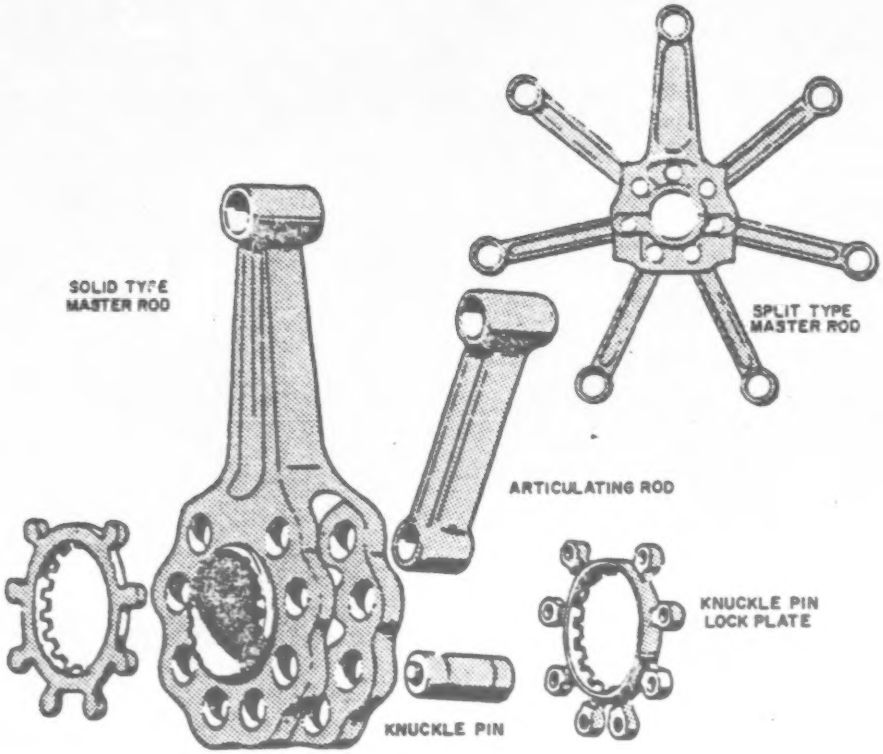

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Figure 6-10.–Articulating rod assembly.

pins are pressed into holes in the master rod flanges and retained in position by spider-shaped lock plates bolted to the flanges.

Lock Plates

The lock plates have two additional functions besides the one of retaining the knuckle pins in the master rod. They also hold the crankpin or master rod bearings in place and transmit lubricating oil from the crankpin bearing to the knuckle pins.

PISTONS

The piston acts as a moving wall in the combustion chamber. After the air/fuel mixture has been admitted to the cylinder, the piston compresses the mixture, which is ignited by the spark plug at the proper time. The piston then transmits the work accomplished by the combustion of the mixture, and the resulting expansion of gases forces the piston downward. This force is transmitted to the crankshaft through the articulating rod

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(or master rod), and then on the return upward stroke forces the exhaust gases from the cylinder.

Construction

The majority of aircraft engine pistons are machined from aluminum alloy forgings. Grooves are machined in the outside diameter of the piston to receive the piston rings, and cooling fins are provided on the inside of the piston for greater heat transfer to the engine oil.

Pistons may be either the trunk type or the slipper type, both shown in figure 6-11. The top face of the piston, or head, may be either flat, convex, or concave. Recesses may be machined in the piston head to prevent interference with the valves.

As many as six grooves may be machined around the piston to accommodate the compression rings and oil rings. The compression rings are installed in the three uppermost grooves; the oil control rings are installed immediately above the piston pin. The piston is usually drilled at the oil control rings to allow surplus oil scraped from the cylinder walls to pass back into the crankcase. An oil scraper ring is installed at the base of the piston wall or skirt to prevent excessive oil consumption. These portions of the piston walls that lie between each pair of ring grooves are called the RING LANDS.

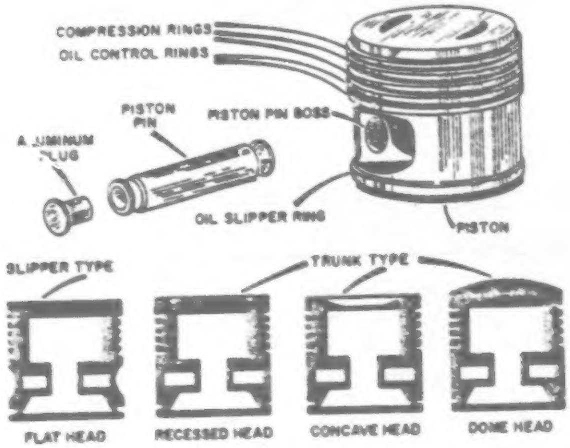

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Figure 6-11.—Piston assembly and types of pistons.

In addition to acting as a guide for the piston head, the piston skirt incorporates the piston pin bosses. The piston pin bosses are of heavy construction to enable the heavy load on the piston head to be transferred to the piston pin.

Piston Pin

The piston pin joins the piston to the articulating rod or master rod. It is machined in the form of a tube from a nickel steel alloy forging, casehardened and ground. The piston pin is sometimes called a wristpin because of the similarity between the relative motions of the piston and the articulating rod and that of the human arm.

The piston pin used in modern aircraft engines is the full-floating type, so called because the pin is free to rotate in both the piston and in the articulating rod piston pin bearing.

The piston pin must be held in place to prevent the pin ends from scoring the cylinder walls. In earlier engines, spring coils were installed in grooves in the piston pin bores at either end of the pin. The modern practice is to install a plug of relatively soft aluminum in one or both of the pin ends to provide a good bearing surface against the cylinder wall.

Piston Rings

The piston rings prevent leakage of gas pressure from the combustion chamber and reduce to a minimum the seepage of oil into the combustion chamber. The rings fit into the piston grooves but spring out to press against the cylinder walls; when properly lubricated, the rings form an effective gas seal.

Most piston rings are made of high grade cast iron. After the rings are made, they are ground to the cross section desired. They are then split so that they may be slipped over the outside of the piston and into the ring grooves which are machined into the piston wall. Since their purpose is to seal the clearance between the piston and the cylinder wall, they must fit the cylinder wall snugly enough to provide a gastight fit; they must exert equal pressure at all points on the cylinder wall; and they must make a gastight fit against the sides of the ring grooves.

Gray cast iron is most generally used in making piston rings. However, many other materials have been tried. In some engines, chrome-plated mild steel piston rings are used in the top compression ring groove because these rings can better withstand the high temperatures present at this point.

COMPRESSION RING.–The purpose of the compression rings is to prevent the escaping of gas past the piston during engine operation. They are placed in the ring grooves immediately below the piston head. The number of compression rings used in the engine on each piston is determined by the type of engine and its design, although most aircraft engines use two compression rings plus one or more oil control rings.

The cross section of the ring may be rectangular or wedge shaped with a tapered face. The tapered face presents a narrow bearing edge to the cylinder wall which helps to reduce friction and provide better sealing.

OIL CONTROL RINGS.—Oil control rings are placed in the grooves immediately below the compression rings and above the piston pin bores. There may be one or more oil control rings per piston; two rings may be installed in the same groove, or they may be installed in separate grooves. Oil control rings control the thickness of the oil film on the cylinder wall. If too much oil enters the combustion chamber, it will burn and leave a thick coating of carbon on the combustion chamber walls, the piston head, and the valve heads. This carbon can cause the valves and piston rings to stick if it enters the ring grooves or valve guides. In addition, the carbon may cause detonation, preignition, or excessive oil consumption. To allow the surplus oil to return to the crankcase, holes are drilled in the piston ring grooves or in the lands next to these grooves.

OIL SCRAPER RING.–The oil scraper ring usually has a beveled face and is installed in the groove at the bottom of the piston skirt. The ring may be installed with the scraping edge away from the piston head or in the reverse position, depending upon cylinder position and the engine series. In the latter case, the scraper ring retains the surplus oil above the ring on the upward piston stroke, and this oil is returned to the crankcase by the oil control rings on the downward stroke.

CYLINDERS

The portion of the engine in which the power is developed is called the cylinder. The functions of the cylinder are to provide a combustion chamber where the burning and expansion of gases take place, and to house the piston and the articulating rod (or master rod).

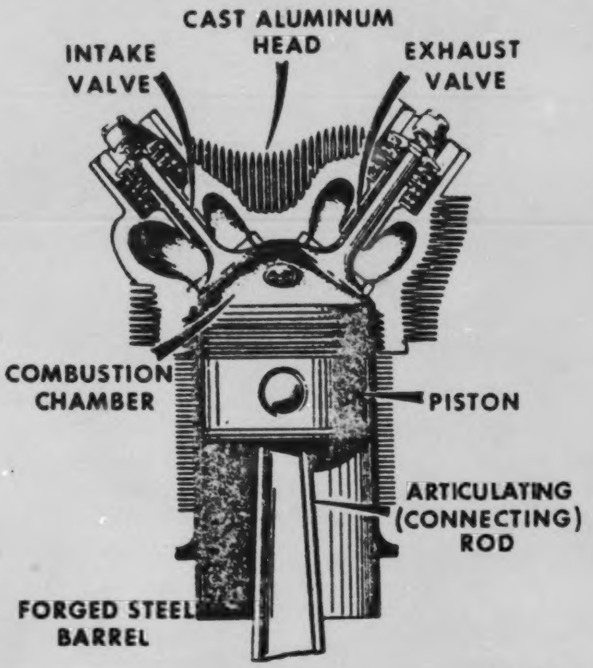
There are four major factors that need to be considered in the design and construction of the cylinder assembly. These are as follows:

1. It must be strong enough to withstand the internal pressures that are developed during engine operation.
2. It must be constructed with a lightweight metal that will reduce the total engine weight.
3. It must have good heat conducting properties so that it can obtain efficient cooling.
4. It must be comparatively easy and inexpensive to manufacture, inspect, and maintain.

The cylinder that is used in the air-cooled radial engine is the overhead valve type shown in figure 6-12. Each cylinder is an assembly of two major parts: The cylinder head and the cylinder barrel. At assembly, the cylinder head is expanded by heating and then screwed down on the cylinder barrel, which has been chilled; thus, when the head cools and contracts, and the barrel warms up and expands, a gastight joint results.

Cylinder Heads

The purpose of the cylinder head is to provide a place for combustion of the air/fuel mixture and to give the cylinder more heat conductivity for adequate cooling. The air/fuel mixture is ignited by the spark in the combustion chamber and commences burning as the piston travels towards top dead center on the compression stroke. The ignited charge is rapidly expanding at this time and pressure is increasing so that as the piston travels through the TDC position it is driven downward on the power stroke. The intake and exhaust valve ports are located in the cylinder head along with the spark plugs and the intake and exhaust valve actuating mechanisms.



AD.41

Figure 6-12.–Cutaway view of a cylinder assembly.

The cylinder head is usually made from aluminum alloy because of its light weight and its excellent heat conductivity. Whenever greater strength is desired, the cylinder heads are forged but they are usually made by the casting process. After casting, the spark plug bushings, valve guides, rocker arm bushings, and the valve seats are installed in the cylinder head. The valve seats are circular rings of hardened metal which protect the relatively soft metal of the cylinder head from wear of the hammering action of the valves and from the hot exhaust gases. Notice the extra large cooling fin area in the vicinity of the exhaust valve in figure 6-12.

Cylinder Barrels

In general, the cylinder barrel in which the piston operates must be made of a high-strength material, usually steel. It must be as light as possible. It must have the proper characteristics for operating under high temperatures. It must be made of a good bearing material and it must have high tensile strength.

The cylinder barrel is made of a steel alloy forging with the inner surface hardened to resist wear of the piston and the piston rings which bear against it. This hardening is usually done by exposing the steel to ammonia or cyanide gas while the steel is very hot. The steel soaks up nitrogen from the gas which forms iron nitrides on the exposed surface. As a result of this process, the metal is said to be nitrided.

The barrel will have threads on the outside diameter at one end so that it may be screwed into the cylinder head. Most air-cooled cylinder barrels have replaceable aluminum cooling fins attached to them, although some may have the cooling fins machined as an integral part of the barrel.

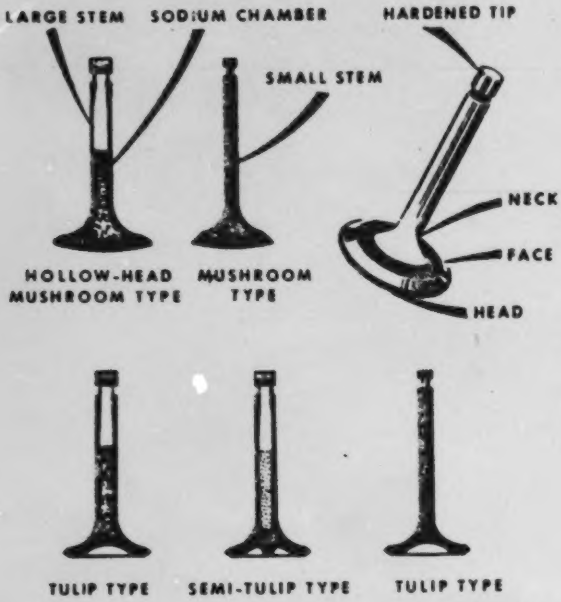
VALVES

Valves are the means with which the air/fuel mixture is permitted to enter the cylinders and the burned gases are expelled. The valves that are used in aircraft engines are of the conventional poppet type; they are called this because of the popping action that takes place when they are lifted off of the valve seats. The valves are also typed as to their shape and are called either MUSHROOM or TULIP because of their resemblance to these plants. Figure 6-13 illustrates the various shapes and types of these valves.

Construction

The valves in the cylinders of an aircraft engine are subjected to high temperatures, corrosion, and operating stresses that require a metal alloy that is able to resist all of these factors. The valves of the R-3350 engine are constructed of forged steel, having a cobalt tip. The intake valve has a stellite face and the exhaust valve has a nichrome face.

The head of the valve is that part which serves to open and close the cylinder ports. The head has a ground face, which forms a seal against the ground valve seat in the cylinder head when the valve is in the closed position. The valve stem acts as a pilot for the valve head and rides in the valve guide installed in the cylinder head for this purpose. The neck is the part that forms the junction between the head and the stem. The tip of the valve is hardened



AD.42

Figure 6-13.–Valve types.

to withstand the hammering of the valve rocker arm as it opens the valve.

Both valves used in the R-3350 engine are of the mushroom type, are the same weight, are partially filled with sodium, but are not interchangeable. The faces of the valves, as noted above, are not constructed of the same material. The valves may be identified in this manner; the intake valve will have a flat milled on the tip to identify it.

Both the intake valve and the exhaust valve are partially filled with metallic sodium. This material is an excellent heat conductor and is placed in the valve for this purpose. The sodium will melt at approximately 208°F and the reciprocating motion of the valve circulates the liquid sodium and enables it to carry away heat from the valve head to the valve stem, where it is dissipated through the valve guide to the cylinder head and the cooling fins. Thus the operating temperature of the valve may be reduced 300° to 400°F.

NOTE: Exposure of the sodium contained in these valves to the outside air will result in fire, explosion, and injury to personnel in the vicinity. Do not maltreat this type valve or attempt to break or cut it open.

In some engines, the intake valve may be of the tulip type and have a smaller stem than the exhaust valve, or it may be similar in appearance to the exhaust valve but have a solid stem and head. However, present practice in high-powered engines is to use the same type of valve in both the intake and exhaust.

VALVE-OPERATING MECHANISM

The valve-operating mechanism consists of those components necessary to open and close the valves at the correct points in the operating cycle. In a radial engine, the major components of the valve-operating mechanism are the cam ring, the cam followers or tappets, the push rods, the rocker arms, and the valve springs. These parts are shown diagrammatically in figure 6-14.

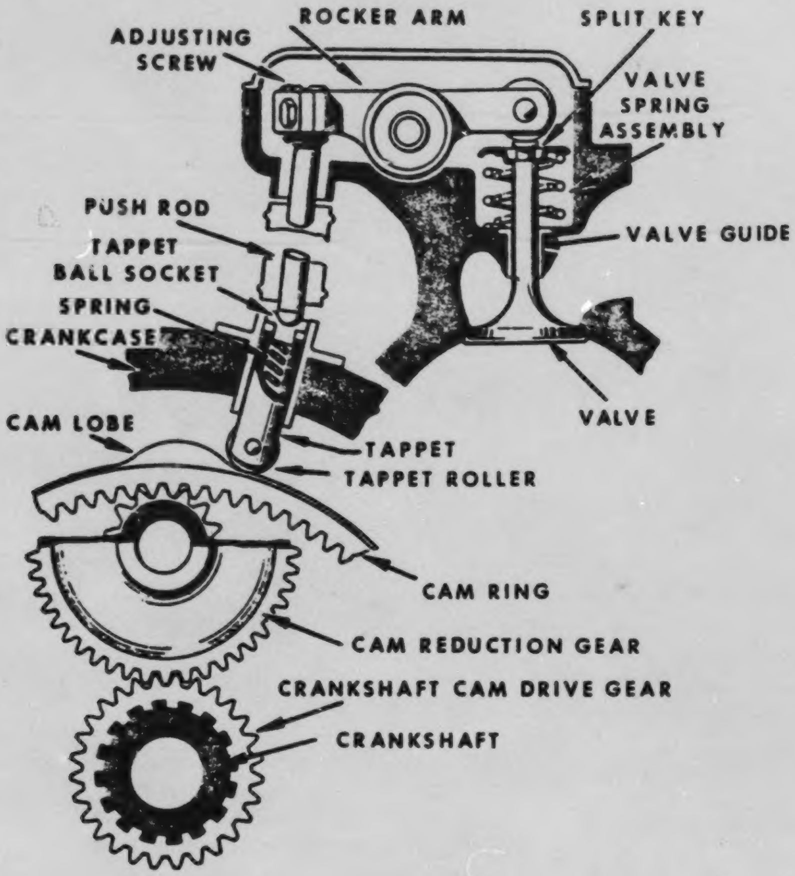
Cam Ring

In a single-row radial engine, the cam ring is located between the propeller reduction gearing and the front end of the power section. In a twin-row radial engine, a second cam for the operation of the valves in the rear row is installed between the rear end of the power section and the supercharger section.

The cam ring is mounted concentrically with the crankshaft and is driven by the crankshaft at a reduced rate of speed through the cam intermediate drive gear assembly. The cam ring has two parallel sets of lobes spaced around the outer diameter, one set (cam track) for the intake valves and the other for the exhaust valves. The cam rings used in an R-3350 engine have four lobes on both the intake and the exhaust tracks, and the timing of the valve events is determined by the spacing of these lobes and the speed at which the cam rings are driven in relation to the speed of the crankshaft. The valve lift (distance that the valve is lifted off of its seat) and the valve duration (length of time the valve is held open) are both determined by the shape of the cam lobes.

Tappet Assembly

The tappet assembly consists of a cylindrically shaped tappet, which slides in and out in a tappet guide installed in one of the crankcase


ROCKER ARM
SPLIT KEY
ADJUSTING SCREW
VALVE SPRING ASSEMBLY
PUSH ROD
VALVE GUIDE
TAPPET BALL SOCKET
SPRING
CRANKCASE
VALVE
CAM LOBE
TAPPET
TAPPET ROLLER
CAM RING
CAM REDUCTION GEAR
CRANKSHAFT CAM DRIVE GEAR
CRANKSHAFT

AD.43

Figure 6-14.–Valve-operating mechanism (radial engine).

sections over the cam ring; a cam follower or tappet roller, which follows the contour of the cam ring and lobes; a tappet ball socket or push rod socket; and a tappet spring. The function of the tappet assembly is to convert the rotational movement of the cam lobe into reciprocating motion and to transmit this motion to the push rod, rocker arm, and then to the valve tip, opening the valve at the proper time. The purpose of the tappet spring is to take up the clearance between the rocker arm and the valve tip in order to reduce the shock load when the valve is opened.

Push Rod

The push rod is constructed of hollow steel tubing with hardened ball-shaped ends. The push rod transmits motion from the tappet assembly to the rocker arm; it is enclosed in a tubular housing that extends from the crankcase to the cylinder head.

Rocker Arm

The rocker arm, mounted in the rocker arm housing or rocker box in the cylinder head, transmits the motion of the push rod to the valve. This arm is provided with an adjusting screw which provides for the adjusting of the clearance at the valve stem tip. The screw is always adjusted to give a slight clearance at the valve stem tip to make sure that the valve closes fully.

Springs

Two or more concentric valve springs are used for each valve in the majority of aircraft engines. The springs are held in place by split locks installed in the recess of the valve spring upper retainer or washer, and engage a groove machined into the valve stem. The functions of the valve springs are to close the valve and to hold the valve securely on the valve seat.

BEARINGS

There are three types of bearings in use in the radial engine—plain, roller, and ball. Ball and roller bearings are used in the engine wherever possible.

Plain Bearings

Plain bearings are generally used for the crankpin, cam ring, knuckle pin, piston pin, and the accessory drive shaft bearings. The valve guides and the tappet guides are also plain bearings. However, the motion of the parts of which they support is reciprocating instead of rotary.

Plain bearings are usually made of nonferrous (having no iron) metals, such as bronze, aluminum, and various alloys of copper, tin, and lead. Master rod or crankpin bearings in some engines, such as the R-3350, are thin shells of steel, plated with silver on both the inside and the outside surfaces and with lead-tin plated over the silver on the inside diameter only. Smaller bearings, such as those used to support various shafts in the accessory section, are called bushings. Porous bushings are widely used in this instance. They are Oilite bushings. They are impregnated with oil so that the heat of friction brings the oil to the bearing surface during engine operation.

Ball Bearings

A ball bearing assembly consists of grooved inner and outer races, one or more sets of balls, and, in bearings designed for disassembly, a bearing retainer. They are used for supercharger impeller shaft bearings and rocker arm bearings in some engines. Special deep groove ball bearings are used in aircraft engines to transmit propeller thrust to the engine nose section.

Roller Bearings

Roller bearings are made in many types and shapes, but the two types generally used in the aircraft engine are the straight roller and the tapered roller bearings. Straight roller bearings are used where the bearing is subjected to radial loads only. In tapered roller bearings, the inner- and outer-race bearing surfaces are cone shaped. Such bearings will withstand both radial and thrust loads. Straight roller bearings are used in the R-1820 and the R-3350 engines for the crankshaft main bearings.

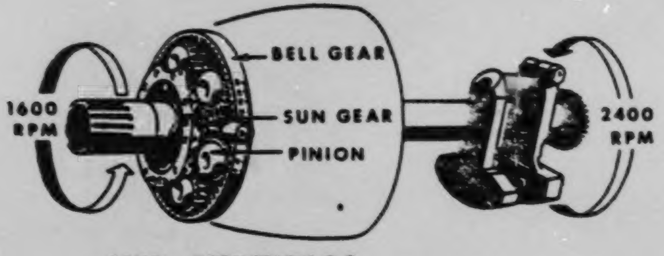
PROPELLER REDUCTION GEARING

The increased brake horsepower developed by modern aircraft engines results partly from increased crankshaft speeds. It is therefore necessary to drive the propeller through a system of reduction gearing in order to reduce the speed of propeller rotation to enable the propeller to operate efficiently. Whenever the speed of the blade tips approach the speed of sound the efficiency of the propeller deteriorates rapidly. Another reason that it is necessary to reduce the propeller rpm is that a higher horsepower can be developed in the engine and consequently a greater power output can be obtained than would be possible if the propeller was directly driven by the crankshaft.

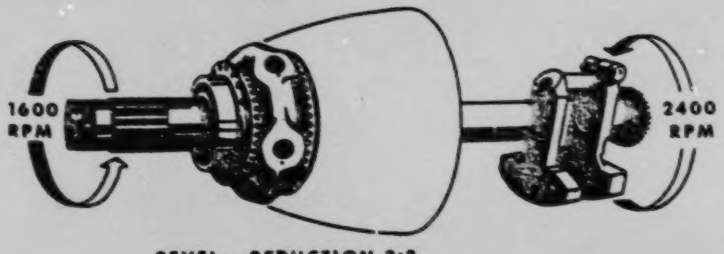
The reduction gearing in the radial engines used by the Navy is of the planetary type. It is called planetary because in this system small pinion gears rotate about an inner gear, as the planets rotate about the sun. Two types of planetary gear systems are used: The bevel planetary gear and the spur planetary gear. Both types are shown in figure 6-15.

Spur Planetary Type

The R-3350 engine, which has a spur planetary type reduction system, has a driving gear splined to the front section of the crankshaft, a stationary gear secured to the nose section, and 20 pinion gears rotating in a pinion carrier assembly that is bolted to the propeller shaft.



SPUR-- REDUCTION 3:2



BEVEL-- REDUCTION 3:2

Figure 6-15.—Planetary reduction gears. AD.44

As the driving gear is turned by the crankshaft, the planetary pinions are rotated around their own axes. The teeth of the planetary gears, however, are in mesh with the stationary gear. As they revolve they also walk around the stationary gear. Since the pinions are mounted on a carrier assembly which is bolted to the prop shaft, it also rotates. This system provides a propeller shaft to crankshaft ratio of 0.4375:1.

In the other type of spur planetary gearing, the position of the gears is reversed; the inner (sun) gear is secured to the crankcase front section and forms the fixed gear, while the outer (bell) gear is splined to the crankshaft. The operating principle, however, is the same.

Bevel Planetary Type

The bevel type of planetary gearing operates on the same principle as the spur planetary type. The driving gear is machined with external beveled gear teeth and is attached to the crankshaft. A set of mating bevel pinion gears is mounted in a cage which is attached to the propeller shaft. The pinion gears are driven by the driving gear and walk around the stationary bevel gear, which is bolted to the nose section of the crankcase.

The propeller reduction gear ratio, that is, the ratio between the speed of the crankshaft and the speed of the propeller shaft, varies in different engines according to the type of propeller used as well as other considerations. Obviously, a propeller having two blades would have to be driven at a higher rotational speed than a propeller having three or four blades.

PROPELLER SHAFTS

Except for a difference in the pinion flange and in the size of the shaft, the propeller shafts used in all modern high-power engines are similar. The shaft is threaded at the forward end for the propeller attaching nut. Splines located to the rear of these threads engage similar splines in the propeller hub. A shoulder towards the rear of the propeller shaft provides a seat for the inner race of the propeller thrust bearing. The shaft is threaded forward of the thrust bearing seat for the installation of the thrust bearing nut which retains the bearing in place. The shaft is generally hollow throughou its length and carries the oil passage required for the operation of hydraulically controlled propellers.

POWER RECOVERY

Recovery of power that is usually lost through the exhaust system is accomplished through the use of three blowdown type turbines (power recovery turbines), which have the exhaust gases from the cylinders ported through them. Each turbine receives the exhaust gases from six cylinders, three front and three rear. The gases enter the turbine at the nozzle and cause the turbine wheel to spin at a high rate of speed. The turbine wheel is connected to the engine through a system of gearing and shafting and a fluid coupling which allows the energy developed to be returned to the crankshaft. The power that may be recovered will approximate 450 brake horsepower at the maximum power output of the engine.

SUPERCHARGER REAR HOUSING AND ACCESSORY DRIVES

Located aft of the front supercharger housing is the rear supercharger housing and cover. The supercharger rear housing provides a mounting pad for the carburetor (or master control if it is a direct fuel injection engine), a mounting pad on either side of the carburetor for mounting the direct fuel injection pumps, and also mounting pads for the engine driven fuel pump, tachometer generator, synchronizing generator, and the rear engine main oil pump and sump.

The rear cover provides for the mounting of the various accessories needed for the operation of the engine and the aircraft. All of these accessories are driven at various speeds through gear takeoffs from the accessory drive and starter shaft. The type of accessories that are mounted here will depend largely upon the mission of the aircraft, but will usually include the following: AC and DC generators, a vacuum pump, hydraulic pump, starter, magneto or magneto generator, etc.

CHAPTER 7

RECIPROCATING ENGINE FUEL SYSTEMS

In general, the reciprocating engine fuel systems found to be most satisfactory may be divided into two parts:

1. The airframe system. This system consists of fuel tanks, with their connecting lines; fuel transfer valves; selector and shutoff valves to establish an emergency system; and fuel tank boost pumps.
2. The engine system. This system includes filters, engine-driven fuel pumps, carburetor, etc.

Both the airframe fuel system and engine fuel system are discussed in this chapter. Operation and maintenance of fuel systems are also included.

NOTE: To help the ADR to understand the fuel systems for reciprocating engine aircraft, the type, designation, and requirements of the fuel used by the reciprocating engine are also covered.

AVIATION GASOLINE

Aviation fuel is a liquid containing hidden energy, which by the process of cumbustion is released as heat and is turned into mechanical energy in the engine. This mechanical energy is then used to produce thrust, which propels the aircraft. The basic requirement of furnishing energy is, however, qualified by a number of other requirements which are almost as basic, since there are many liquids whose potential energy cannot be utilized to produce mechanical energy in aircraft engines.

An engine fuel must be made to suit the engines in which it is to be used. In the case of the aircraft engine, the fuel must also be suitable for use under a wide variety of operating conditions. There is no such thing as the perfect fuel, since a fuel which is suitable for a combat aircraft piston engine will not work satisfactorily in a diesel engine and vice versa.

While the fuel must be suitable for the engine, the engine must also be suitable for the fuel. Making the engine suitable for the fuel is necessary to insure that adequate supplies are available for the intended use.

Liquid fuels are in many respects ideal fuels for use in internal-combustion engines. For convenience, liquid fuels are classified as either NONVOLATILE or VOLATILE. The former are used in diesel engines. The volatile class includes those fuels which are used commonly with a carburetor and are carried into the engine cylinder in an evaporated or partially evaporated state. Among these are alcohol, benzol, and gasoline. Gasoline is almost universally used in aircraft reciprocating engines.

Gasoline is a blend of liquid hydrocarbons (compounds containing only hydrogen and carbon) ranging in boiling points from approximately 90° to 425°F. These hydrocarbons are present in varying quantities, depending on the source and purpose of the gasoline. The specifications for gasoline are very detailed and exacting to insure that fuel has the desired characteristics. A number of tests are required to determine the suitability of the fuel for a particular engine. However, you, as an Aviation Machinist's Mate R, will be primarily interested in the FUEL GRADE, which is the octane rating and/or the performance number of the fuel and the fuel purity.

In selecting a fuel, there are several factors that must be considered. As one fuel cannot have all the requirements to the greatest degree, the fuel selected must be a compromise of various factors. The most important factors involved in the choice of a fuel are as follows:

1. Heat energy content.
2. Volatility.
3. Antiknock value.
4. Storage stability.
5. Purity.

The meaning and importance of these factors are discussed in the following sections.

HEAT ENERGY CONTENT

A fuel satisfactory for aircraft engines must have a high potential heat energy content per unit weight. By having this high energy content, the weight of fuel to be carried is lower than if a low energy content fuel is used, so that more of the load carrying capacity is available for the payload.

VOLATILITY

Volatility is defined as the vapor-forming characteristics of a substance. Since liquid fuels must be in a vaporous state to burn, volatility is an important property to be determined in choosing a suitable fuel for an aircraft engine. The volatility of the fuel has an effect on its starting, accelerating, vapor locking, and distribution characteristics. Gasoline is a very satisfactory fuel in this respect, since it can be blended during refining to give the desired characteristics.

ANTIKNOCK VALUE

The antiknock value of a fuel (its ability to resist detonation) is of great importance in aircraft reciprocating engines. Due to the high compression pressures in the engine, brought about either by high compression ratios, a high degree of supercharging, or both, some fuels have a tendency to increase their rate of burning during the combustion process, causing an explosive combustion called detonation. Detonation causes a loss of power and engine damage. By use of a fuel of a high antiknock value, it is possible to reduce detonation tendencies and increase the power output and the efficiency of an engine. Gasoline can be manufactured and blended in a manner to give a very high antiknock value.

Octane Rating

Iso-octane is a reference fuel having a very high antiknock value. Normal heptane is a reference fuel having a very low antiknock (high detonation) value. A mixture of the two will have an antiknock value somewhere between these two extremes. The antiknock value of the mixture will vary with the proportions of the mixture. Increasing the percentage of iso-octane in the mixture (decreasing the proportion of normal heptane) increases the antiknock (octane number) value of the mixture. The octane number (antiknock value) of a fuel is equal to the percentage of iso-octane in the mixture having the same knock characteristics as the fuel in question.

To perform the test for octane rating, a single-cylinder knock test engine is utilized. Two float chambers are incorporated in the carburetor so that the fuel being tested can be fed from one chamber and the iso-octane heptane mixture from the other. The engine, under load conditions which will produce slight detonation, is operated alternately on the fuel to be tested and the known test mixture. A test of a mixture of iso-octane and heptane is found which exactly matches the antiknock value of the fuel under test in the opposite float chamber. Thus, for example, if the fuel under test is equal in antiknock characteristics to a mixture of 70-percent iso-octane and 30-percent normal heptane, the rating given the fuel is 70 octane. It is readily apparent that octane ratings may not exceed 100 percent. The method of rating fuels with an antiknock value greater than iso-octane is discussed in the following paragraphs.

Performance Numbers

As previously explained, if a fuel has an antiknock value greater than iso-octane, it must be rated on a different scale. This scale is called performance number and is obtained by adding tetraethyl lead (ethyl) to iso-octane for a new reference fuel.

When rating fuels for performance number, their antiknock characteristics are compared to this new reference fuel. Thus, for example, if the fuel to be rated equals the antiknock characteristics for iso-octane plus 3 cm^3 (cubic centimeters) of lead per gallon, this fuel would be rated as having a performance number of 146. This indicates than an engine operating on this fuel would be able to develop 46 percent more power than if it were operating on straight iso-octane.

Fuel Grades

When the fuel grade includes a number of 100 or less, this number indicates the octane number, If the number is above 100, it is known as the performance number. When the grade includes two numbers such as grade 100/130 or grade 91/96, the first number indicates the rating at lean mixture conditions and the second indicates the rating at rich mixture. Thus, grade 100/130 indicates a lean mixture rating of 100 performance number (also 100 octane number) and that the rich mixture performance number is 130. The addition of tetraethyl lead to any fuel will increase its antiknock value in both lean and rich mixtures, but not to the same degree. The first and second figures in grade 91/96 both refer to octane numbers of fuel containing tetraethyl lead.

AIRFRAME FUEL SYSTEM

The airframe fuel system provides a controlled means of receiving fuel from external sources and supplying fuel from tanks and cells within the aircraft to the engines. The airframe fuel system is made up of the main fuel system and the auxiliary fuel system. The main fuel system consists of fuel tanks, cells, and plumbing permanently mounted in the aircraft fuselage and wings. The auxiliary fuel system consists of drop tanks mounted on pylongs under the wings or attached to the wingtips.

NOTE: Some of the larger aircraft have an internal auxiliary fuel system. The SP-2H, for instance, utilizes two lightweight self-sealing fuel cells that can be mounted side by side in the bomb bay.

The SP-2H fuel system includes six outer wing panel cells and eight center section cells. Also included are two bomb bay and two wingtip tanks which are optional loading. Control of the fuel system is accomplished by two engine-driven fuel pumps, a maximum of seven electric auxiliary booster and transfer pumps, fuel quantity gages, and all necessary plumbing and controls.

Under normal conditions, fuel in the wingtip tanks, bomb bay tanks, and center section tanks is transferred to the main tanks (outer wing panel tanks) before being supplied to the engines. Fuel in the bomb bay tanks is first transferred to the center section tanks before being transferred to the main tanks. Float valves in the center section and main tanks, together with the transfer boost pumps, automatically accomplish fuel transfer, provided the fuel control panel is placed in normal.

OPERATION

Control of the fuel system is accomplished from the pilot's overhead control panel. Control knobs on the panel actuate electric motors, accessible within the fuselage, which in turn are cable-connected to the individual fuel selector and crossfeed valves, located aft of each engine nacelle. The individual actuators, which position the fuel valves, can also be positioned manually in case of electrical failure.

In normal use, the fuel is supplied to the engines from the outer wing tanks. As the outer wing tank fuel level drops, float valves automatically allow transfer of fuel in sequence from the wingtip tanks, the center section tank, and the bomb bay tank. In case of an emergency, fuel can be transferred from the center section tanks to the engines.

Fuel Transfer

Normal fuel transfer is accomplished in the following sequence:

1. When the fuel level in the main tank drops to 3,600 pounds (600 gallons), the float valve in the number 3 cell opens, allowing fuel in the wingtip tank to be transferred to the main tank.
2. When the fuel level in the main tank drops to 2,880 pounds (480 gallons), the float valve in the number 1 cell opens, allowing fuel in the center section tank to be transferred to the main tank.
3. When the fuel level in the center section tank drops to 3,600 pounds (600 gallons), the

float valve in the number 1 cell opens, allowing fuel in the bomb bay tank to be transferred to the center section tank.

NOTE: The fuel control panel incorporates a fuel flow diagram. By positioning the tank selector valve controls and fuel flow valve controls to obtain unbroken lines, the course of the fuel flow obtained under various selector valve settings is clearly indicates.

Auxiliary Fuel Transfer

In the event that fuel fails to transfer from the center section tanks to the main tanks, fuel remaining in the center section tanks can be obtained by selecting the center section tanks as the engine feed tanks.

Fuel in tanks on one side of the airplane can be transferred through the crossfeed line to tanks on the opposite side, according to the settings of the fuel tanks selector valves. The transfer-boost pump in the tank receiving fuel must be OFF, the transfer-boost pump in the tank yielding fuel ON, and the boost pump high-low selector switch in the HIGH position.

Engine Supply

Fuel from either outer wing tank or center section tank can feed directly to one or both engines. In normal use, however, fuel is supplied only through the outer wing tanks. The transfer boost pumps in either the center section tanks or the outer wing panel tanks are capable of maintaining fuel pressure to an engine in case the engine-driven fuel pump fails (provided the jet engines are not operating). Fuel crossfeed is available in the SP-2H and is used when an engine failure occurs or when necessary to equalize fuel levels in the left and right wing tanks.

Refueling

Although normal refueling of most models of the SP-2H aircraft is by gravity fueling through the filler units located in each tank, some models are refueled by connecting an outside fuel supply to the aircraft pressure fueling receptacle located in the tip of the engine nacelle, mounted on the aft side of the rear main spar. The aircraft should be fueled in the following sequence—main tanks, center section tanks, wingtip tanks, and the bomb bay tanks.

NOTE: Although the aircraft is normally equipped with circular 200 U.S. gallon wingtip tanks, the elliptical 350 U.S. gallon wingtip tanks are interchangeable. If the aircraft is equipped with the elliptical tanks, fuel loading must be limited to 180 U.S. gallons in each tank.

Defueling

The SP-2H is defueled through the defuel valves (fuel drain Valves). The valves are mounted over the landing gear trunnion, just forward of the bulkhead, below the rear beam on the inboard side of the nacelles, and at the aft end of the lower electronic compartment. The defuel valves are two-position valves which can be operated only at the valves. When the valves are opened, fuel drains from the system through the drain port in the valve.

FUEL CELLS AND TANKS (SP-2H)

The aircraft fuel system consists of the following fuel cells and tanks—outer wing tanks, center section tanks, wingtip tanks, and bomb bay tanks.

The outer wing tanks include three fuel tanks installed in each outer wing panel between wing stations 204 and 420. (Each tank is composed of two interlaced cells.) The cells are constructed of lightweight, bladder type, nonself-sealing, or semirigid, self-sealing cells, depending on the manufacture date of the aircraft.

The center section fuel cells are lightweight bladder type cells and are not of self-sealing construction. They consist of eight cells installed in line in the wing center section, four on each side of the centerline of the fuselage. The four cells on the left are interconnected and act as a single tank, and the four on the right are similarly interconnected.

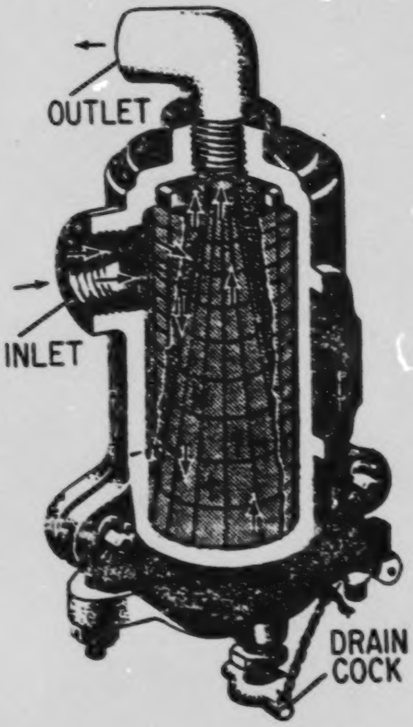
The wingtip tanks are an integral part of the center-mounted, circular nacells installed at each wingtip. Each tip tank is a self-contained unit; the filler neck, drain valve, and transfer pump are all easily accessible, and do not require removal of any other structure. Quick-release plumbing and electrical fittings make it possible to jettison the tanks if desired.

Provisions are incorporated in the bomb bay for two lightweight self-sealing cells. The cells occupy the full length of the bomb bay and are mounted side by side. When both cells are used, they are plumbed together to act as one bomb bay tank. The cells may be jettisoned, if desired, as all connections are of the quick-release type.

STRAINERS

Strainers are installed in the tank outlets, and frequently in the tank filler necks. These are of fairly coarse mesh and prevent only the larger particles from entering the fuel system. Other strainers are provided in the carburetor fuel inlets and in the fuel lines themselves. The latter are fine mesh strainers.

The main fuel strainer shown in figure 7-1 is provided with a fine mesh screen and is installed at the lowest point in the fuel system. The function of the main strainer is important; it not only prevents foreign matter from entering the carburetor, but also because of its location at the low point of the fuel system, traps any small amount of water that is present in the system. In multiengine aircraft, one main strainer is usually installed in each engine nacelle.



AD.45

Figure 7-1.–Main fuel strainer.

In the strainer shown in figure 7-1, the fuel enters at the side, passes through the screen, and leaves at the top. While the fuel is passing through the strainer body, all dirt or sediment settles to the bottom, where it can be removed by opening the drain cock. The drain cock is usually connected by a drain line to an overboard drain connection.

The strainer should be drained before each flight, and the screen removed and cleaned at periodic inspections, with extreme care exercised to prevent damage to the screen.

PUMPS

All aircraft used by the Navy are equipped with pressure feed fuel systems. The basic source for this pressure is the engine-driven fuel pump, but auxiliary fuel pumps or booster pumps are required in every pressure feed system for several purposes: to supply fuel pressure for starting the engine, to supply fuel to the primer system, and for use as an emergency pump in case of failure of the engine-driven unit. The type of pump widely used until recent years is the hand-operated wobble pump, now rapidly being superseded in Navy aircraft by an electrically driven pump. This electrically driven auxiliary pump may be of the same type as the engine-driven pump or may be of the submerged type, called a submerged tank booster pump.

Engine-Driven Fuel Pump

The purpose of the engine-driven fuel pump is to deliver a continuous supply of fuel at the proper pressure at all times during engine operation. The type of pump in universal use at the present time is the positive displacement rotary vane type pump.

A typical engine-driven pump of this type and a diagram showing the operation of the unit are shown in figure 7-2.

Fuel pumps vary in design. Regardless of variations in design, the principle of operation of all vane type fuel pumps is the same.

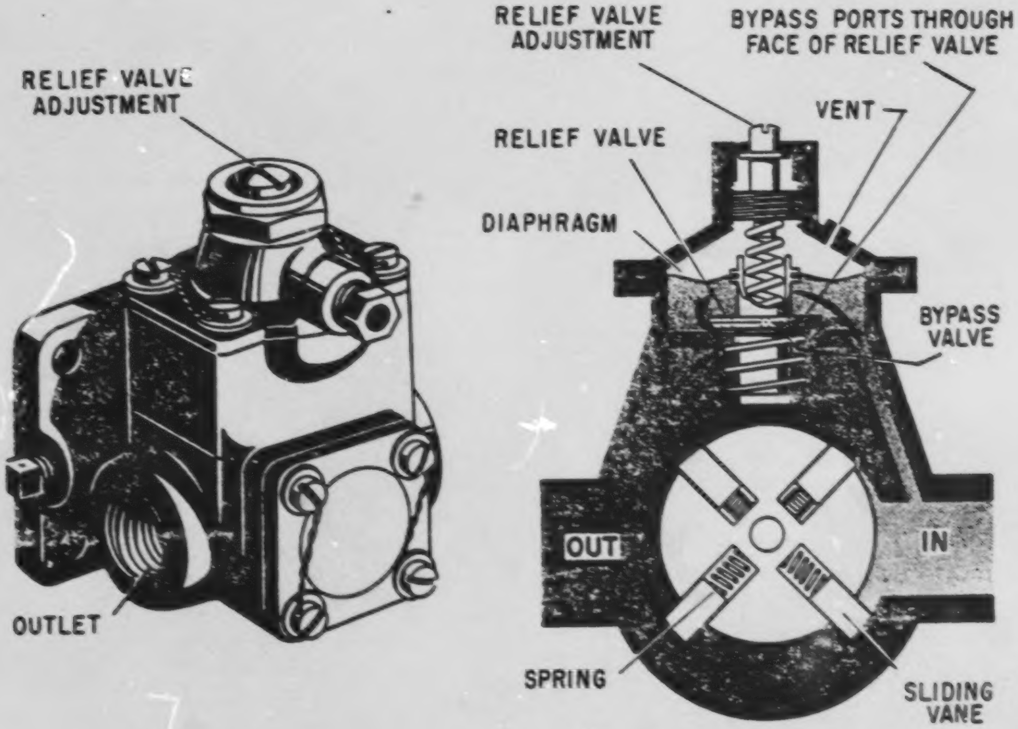
Since the engine-driven fuel pump is turned by a gear train in the accessory section of the engine, it is necessary to provide, within the pump itself, a means of varying the amount of fuel (under constant pressure) delivered to the carburetor to meet the varying demands of different engine power outputs. Constant pressure is maintained by a spring-loaded pressure relief valve. Figure 7-2 shows the pressure relief valve in operation, bypassing excess fuel back to the inlet side of the pump.

Before starting the engine, when the engine-driven fuel pump is not turning, the auxiliary fuel booster pump is used for priming and to deliver fuel under pressure to the carburetor. In order that fuel pumped by the booster pump will pass through the stationary engine-driven pump on its way to the carburetor, it is necessary to incorporate a bypass valve in the engine-driven pump. Both the fuel pressure relief valve and the bypass valve may be contained in the same mechanism.

Auxiliary Fuel Pumps

An auxiliary fuel pump is provided in fuel systems in order to deliver fuel under pressure to the carburetor as required whenever the engine-driven fuel pump is not operating; for example, during starting or in case of failure of the engine-driven fuel pump.

Auxiliary fuel pumps are used during starting to pump fuel to the carburetor and priming system, and may be used as an emergency source of pressure in the case of failure of the engine-driven pump. The electrically driven booster pump is also turned on for takeoff and climb as a standby pressure source and also for high altitude flight, the latter to pressurize the fuel



AD.46

Figure 7-2.–Engine-driven, rotary vane type pump.

supply to the engine-driven pump in order to guard against the possibility of vapor lock.

The type of electrically driven pump that is submerged in the tank, and which serves to pressurize the entire system between the tank and the carburetor operates on the centrifugal principle. These pumps are driven by explosion-proof motors and the design of the impeller is such that it allows only vapor-free liquid fuel to be pumped through the system. This type of submerged pump is shown in figure 7-3.

In some of the later service type aircraft, electrically driven centrifugal pumps are used which have two pumping speeds providing for high-pressure and low-pressure outputs as selected by the pilot. The low-speed position of the pump switch is selected by the pilot for low- and medium-altitude cruise. The pilot selects the high-speed position for takeoff, high-power outputs, and high-altitude flight.

In addition to the purposes outlined above, an auxiliary electrically driven fuel pump of the submerged type may be used to transfer fuel from one tank to another through a crossfeed line incorporated in the fuel system.

Removal and Installation

Specific instructions for the removal and installation of fuel pumps, both auxiliary and engine driven, are given in the appropriate technical publications for a particular aircraft or engine. General instructions are given here.

When working on fuel systems, keep in mind the potential danger in gasoline. All safety precautions must be rigidly enforced.

Before removing a fuel pump, have a suitable container available for catching any fuel which may be in the lines or pump. If the submerged type pump is to be removed, it will be necessary to defuel the tank, or to transfer the fuel to other tanks of the system.

The fuel lines should be disconnected from the pump before removing the holddown nuts. The pump should be pulled straight away from its mounting flange. It is usually necessary to transfer the fuel line fittings from the old pump to the pump to be installed. Compare the new pump with the old one to ascertain that the pumping direction is the same. INLET and OUTLET are marked on the head of the pump. The bypass valve must be installed on the outlet side of the pump.

A new gasket should be used when installing the new pump. The holddown nuts should be tightened to the proper torque with a torque wrench. The nuts should be safetied as soon as possible after being tightened to the proper torque to eliminate the possibility of an oversight.

Carefully inspect the fuel lines and hose clamps, and replace them with new parts if necessary. Install the lines on the fittings and tighten the hose clamps to the proper torque. Carefully inspect for fuel leaks under pressure.

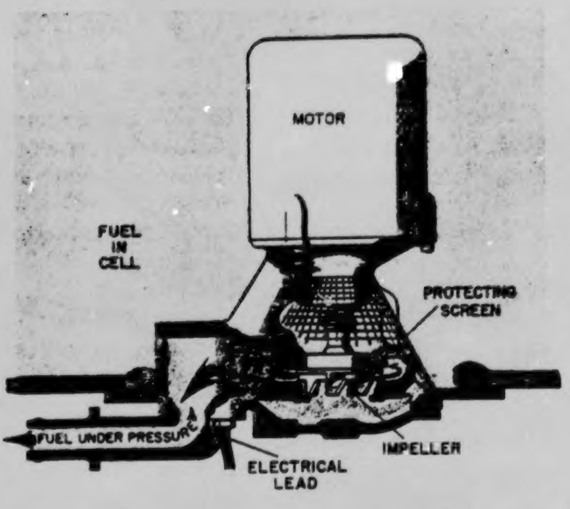


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Figure 7-3.–Submerged boost pump.

FUEL SELECTOR VALVES

One or more selector valves are provided in the system to accomplish the following:

1. Selection of the tanks from which fuel is to be drawn.
2. Selection of the engine or engines to which the fuel is to go.
3. Selection of the tank to receive fuel in tank-to-tank transfer.
4. Routing fuel during refueling operations.
5. Stopping fuel flow.

The size and number of ports, or openings, in selector valves vary with the type of installation. For example, a single-engine aircraft with two fuel tanks and a reserve supply requires a valve with four ports–three inlets from the tanks and a common outlet. The valve must accommodate the fuel flow capacity of the fuel line, must not leak, and must operate easily with a definite "feel" or "click" when it is in the correct position. Selector valves may be operated either mechanically or electrically.

FUEL DRAINS

One or more accessible drains are provided at low points in the fuel system so that all fuel may be completely drained, as necessary, to effect repairs of the system. Drains are usually provided at the main strainer and at the bottom of each tank. It is normal practice to drain a small amount of fuel from aircraft before flight to remove any water which may have accumulated within the fuel system due to condensation, or which may have been introduced into the tanks with the fuel.

FUEL GAGES

The most commonly used instruments which furnish the necessary information concerning the fuel system to the pilot are the fuel quantity gage, the fuel pressure gage, and the fuel flowmeter.

Fuel Quantity Gages

Fuel quantity gages are mounted on the instrument panel in the cockpit, or on the flight engineer's panel in some multiengine aircraft. They indicate, either in pounds or gallons, the total remaining fuel in each individual fuel tank. On some aircraft, one fuel gage, called a TOTALIZER, indicates the total amount of fuel remaining in all of the fuel tanks.

Older type aircraft use a float system to determine the amount of fuel remaining in the fuel tank(s). This type of system is being replaced by the capacitance type system. The capacitance type system of measuring fuel quantity is more accurate in measuring the fuel level, as it measures the fuel by weight instead of in gallons. Fuel volume will vary with temperature (a gallon of gasoline weighs more when it is cold than when it is hot); thus, if it is measured in pounds instead of gallons, the measurement will be more accurate.

Fuel Pressure Gage

The fuel pressure gage indicates the pressure of the fuel entering the carburetor. This gage may be included with the oil pressure gage and the cylinder head temperature gage in one casing, called the ENGINE GAGE UNIT. Most aircraft today have separate gages for each of these functions. They are mounted on the instrument panel of the cockpit, or at the flight engineer's panel, so that the pilot or the engineer can read all of them at a moment's glance. In multiengine aircraft, there is an individual gage for each function of the engine.

Fuel Flowmeter

The fuel flowmeter is normally used only in multiengine aircraft. It indicates to the pilot (or to the flight engineer) the amount of fuel that is being supplied to the carburetor, and for all practical purposes, the amount of fuel being consumed by the engine. A fuel flowmeter, usually calibrated in pounds per hour, is furnished for each engine of multiengine aircraft.

CARBURETORS

The objective of the carburetor is to mix with the air going into the engine the proper weight of fuel for all, operating conditions in accordance with a predetermined mixture formula. The basic requirements of a carburetor are the same, regardless of the type of carburetor employer or the model engine on which it is installed. Therefore, in the following paragraphs the model 58-CPB11 carburetor and the model PR-58S2 master control are covered as typical controls, and the model PR58T1 injection carburetor is covered for comparison.

TYPES

There are two types of carburetors in common use on naval aircraft today–the float type and the pressure injection type. Of the two types, the pressure injection carburetor is the most widely used.

DESIGNATIONS

Each carburetor used on Navy aircraft has a model designation to identify the individual type.

In the following paragraphs the meaning of each letter and number in the model designations is explained. Stromberg types are discussed first, followed by the Chandler-Evans.

Stromberg

The first part of the Stromberg designator is a prefix, consisting of a letter or series of letters and indicating the type of carburetor. Stromberg types in common use are as follows:

NA–Natural atomization (commonly called the float type).

P–Pressure type with regulator valve at the fuel inlet.

Another letter, which indicates the type of barrel, always follows the prefix. The letters and their meanings on NA type carburetors are as follows:

R–Single barrel, single float.

D–Double barrel, single float in chamber to the rear.

An example is NA R9C2, and is interpreted as follows:

NA–Natural atomization.
R–Single float.
9–Barrel size.
C–Major modification.
2–Minor modification.

The letters for the Stromberg P series are as follows:

R–Rectangular barrel.
D–Double barrel.

An example is PD12K10, and is interpreted as follows:

12–Barrel size.
K–Major modification.
10–Minor modification.

SIZE NUMBER.–The number following the type letter indicates the size of the carburetor barrel. For a carburetor with cylindrical barrels, each unit increase in size number, above the numeral 1, indicates an increase of one-fourth inch in the barrel diameter. The basic number (1) has a value of 1 inch in the NA series, and 1-3/16 inch in the P series. Each additional number above the basic number indicates a 1/4-inch increase in barrel diameter. The designation PD 12 would indicate a barrel diameter of 3-15/16 inches, and NAR 9 would indicate a barrel diameter of 3 inches.

For carburetors with rectangular barrels, the size number indicates the inside area of the engine mounting flange in square inches.

MODEL LETTER.–The letter following the size number is used to indicate a major design change which distinguishes a new model from preceding ones.

MODEL MODIFICATION NUMBER.–The number following the model letter indicates that there are only slight differences between similar models. For example, PD12H1, PD12H2, and PD12H3 carburetors are alike except for minor differences.

Chandler-Evans

An example of a Chandler-Evans designation is 58-CPB11. It is interpreted as follows:

58–Number of square inches opening at the mounting flange.

CP–Constant pressure, direct metering type.

B–Model change.

11–Model modification.

The serial number of the Chandler-Evans carburetor also contains information that is pertinent:

1. First two numbers–year of manufacture.
2. Third numeral and letter.
   a. Designator number, indicates the basic parts list setting number of the carburetor.
   b. At the present there are three basic parts list setting numbers in use, 13,000, 14,600, and 49,300.
      (1) 5B–Designator number for the 13,000 parts list number.
      (2) 5F)Designator number for the 14,600 and 49,300 parts list number.
3. Remaining numerals in the serial number contain the shipping sequence number.

An example is 555F159, and is explained as follows:

55–Shipped in 1955.
5F–Parts list group 14,600.
159–159th unit shipped in 1955.

The parts list number which is also located on the nameplate contains the following information:

1. Numbers in front of the dash indicate the basic parts group list.
2. Alphabetical/numerical suffic following the dash–
   a. Indicates design changes which affect interchangeability of detail parts.

b. Carburetors having the same suffix are interchangeable as to functional parts and installation.

c. Suffic numbers should be checked against the section B allowance list or engine logbook before installation of the carburetor.

OPERATING PRINCIPLES

Although all carburetors are designed to deliver the desired fuel/air mixture for all engine operating conditions, they accomplish this in different ways. Therefore, the operating principles of the 58-CPB11 and Stromberg carburetors are discussed separately in the following paragraphs.

58-CPB11

The model 58-CPB11 carburetor is a direct-metering pressure type carburetor that delivers fuel to the spinner injection valve in the correct proportion to the weight of the air passing through the throttle valves. The carburetor meters fuel in the desired air/fuel ratio to meet the many differing conditions under which the engine may be operated. It maintains these air/fuel ratios automatically throughout the operating range of the engine regardless of the temperature or density of the surrounding air or the altitude at which the engine is operated up to its service ceiling.

Airflow to the engine is controlled by the throttle valve opening and is measured by the venturi. A boost venturi is used in the carburetor to amplify the measurement of the airflow. The air passing through the boost venturi is in proportion to the amount being consumed by the engine.

The airflow, as indicated by venturi suction, is used to control fuel flow to the engine through the action of the pressure regulator assembly, which consists of a pressure regulator valve and three diaphragms in series. As the throttles are opened, the venturi suction increases, causing the pressure regulator to move open. This permits more fuel to enter the metering chamber until the fuel pressure against the fuel diaphragm balances the metered suction differential on the air diaphragm and the discharge fuel pressure on the fuel balance diaphragm. The ratio of fuel forces to air forces remains constant and, therefore, any change in airflow to the engine will result in a proportionate change in fuel flow.

To compensate for the decrease in density of the air as the altitude and/or air temperature are increased, an automatic mixture control is provided. This consists of an altitude valve, controlled by an oil and nitrogen filled bellows, placed in series with the boost venturi. A decrease in air density causes the bellows to expand, moving the altitude control valve further into its seat, thereby restricting the airflow through the boost venturi.

Five jets and a diaphragm-actuated "B" valve are provided in the carburetor to take care of varying mixture ratios called for by changing engine operating conditions. A sixth jet and six bleeds are utilized for flow limiting purposes.

Under engine idling conditions, the desired mixture varies from that controlled by the air metering system. A throttle-operated idle valve in the fuel discharge passage provides for control of the mixture. An adjustment on the linkage between the throttle and the idle valve provides a means for obtaining the correct idling mixture.

To compensate for slow reaction of the fuel metering system at rapid acceleration of the engine, a piston is provided at the rear end of the idle valve. Sudden throttle opening will force a fuel charge into the discharge pressure balance line, raising the pressure on the balance diaphragm of the regulator valve to provide immediate additional fuel necessary for rapid acceleration of the engine.

Stromberg

The Stromberg injection carburetor is a hydromechanical device employing a closed feed system from the fuel pump to the discharge nozzle. It meters fuel through fixed orifices according to the mass airflow through the throttle body and discharges it under a positive pressure.

The carburetor is an assembly of the following units: throttle body, automatic mixture control, regulator unit, fuel control unit, and some have adapters.

THROTTLE BODY.–The purpose of the throttle body is to measure and control the airflow; all air entering the engine must flow through the throttle body. This airflow is measured, both by volume and by weight, in order that the proper amount of fuel can be added to meet the engine demands under all conditions. Bernoulli's principle, which states that an increase in velocity will cause a decrease in pressure is applied to the boost venturi in order to get an accurate measurement of volume airflow to the engine. This low-pressure measurement is vented to chamber "B" (or low-pressure side of the air diaphragm), while a sample of the carburetor inlet air is being picked up by the impact tubes and directed to the automatic mixture control (AMC), which measures the air density and is directed on to chamber "A" (or the high-pressure side of the air diaphragm). The pressure differential of the two chambers acting upon the air diaphragm is known as the air metering force, which tends to open the poppet valve. (See fig. 7-4.)

As air flows through the boost venturi, it is measured in accordance with Bernoulli's principle. It is by measuring this low pressure that we can calculate the airflow. At the same time, this low pressure is used to operate the air diaphragm and establish the air metering force.

The throttle body controls the airflow with the throttle valves. The throttle valves may be either rectangular or disk shaped, depending on the design of the carburetor. The valves are mounted on a shaft which is connected by linkage to the idle valve and to the pilot's "throttle" control in the cockpit.

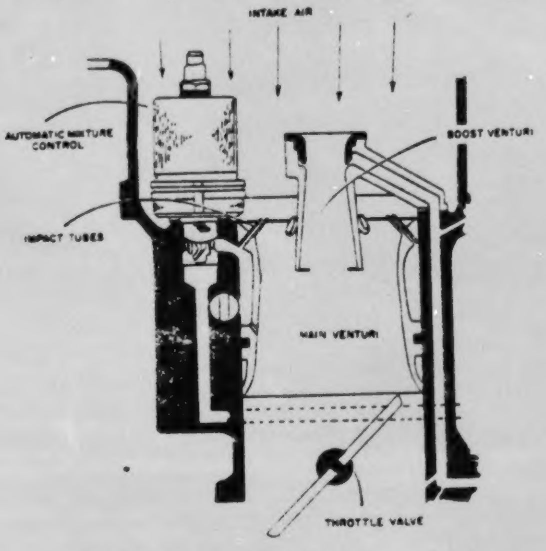

Figure 7-4.–Throttle body and automatic mixture control (AMC). AD.48

The throttle stop limits the travel of the throttle valve and has an adjustment which sets engine idle speed.

The main venturi increases the efficiency of the boost venturi by aiding in setting up the low-pressure area.

The impact tubes take a sample carburetor inlet air and direct it to the AMC and then on to chamber "A."

AUTOMATIC MIXTURE CONTROL–The purpose of the AMC is to compenssate for changes in air density and temperature due to altitude changes. The AMC is a sealed metallic bellows. Inside the bellows are nitrogen and oil. The nitrogen compensates for changes in air density and temperature. The oil is used to dampen the effect of engine vibration. Nitrogen is used, rather than some other gas, because it is chemically stable, or it remains the same when exposed to other materials.

One end of the bellows is recessed to receive the needle, which in turn, is secured to the bellows by a snapring. There is also a spring that extends up against the needle at the point where it is attached to the bellows. The purpose of the needle valve spring in the AMC is to stabilize the movement of the bellows-operated needle, thereby preventing the size of the needle valve seat restriction from being changed due to engine-vibration.

The AMC is sealed at 28 inches of mercury absolute pressure; therefore, any change in the existing atmospheric pressure will cause a reaction of the bellows. As the AMC is taken to higher altitude, where it is exposed to a gradual but definite change in existing atmospheric pressure, the bellows will expand and tend to equal the outside pressure. This action of the bellows will cause the needle to move. Then, as the AMC is brought back towards sea level and the pressure on the outside becomes greater, the bellows will contract.

The AMC is located on the throttle body and is so situated that the needle protrudes into the passage through which the impact pressure passes to "A" chamber. (See fig. 7-4.) At altitudes, then, the expansion of the bellows will cause the needle to restrict the flow of air to "A" chamber, causing a drop in "A" chamber pressure and a lowering of the pressure differential between chambers "A" and "B." This will cause the fuel metering force to close the poppet valve until the fuel metering force equals the air metering force. The AMC can be cleaned in the field, provided the lead seal at the point of adjustment is not disturbed.

REGULATOR UNIT.–The purpose of the regulator unit is to regulate the fuel pressure to the inlet side of the metering jets of the fuel control unit. The regulator unit, then, is a "pressure regulator." (See fig. 7-5.) The unit has at its disposal the pressure maintained by the fuel pump. This pressure is automatically regulated by the regulator unit according to the mass airflow. The throttle body sets up a pressure differential which, through passages, is vented to opposite sides of the air diaphragm. This is known as the air metering force. Attached to this diaphragm is a stem which has a poppet valve on the other end. The poppet valve is arranged so that it opens as the airflow through the throttle body increases and tends to close as the airflow decreases. As the throttle closes, there is a point at which the air metering force is no longer strong enough to open the poppet valve.

At this point, a spring in the regulator unit takes over the control of the valve. This spring is known as the idle spring. It holds the poppet valve open in the idle range. The pressure regulated by the poppet valve is used to set up a "fuel metering force." The fuel metering force will always oppose the air metering force, and the two forces must always be equal, except in the idle range, when the fuel metering force overcomes the air metering force and the idle spring comes in to aid the air metering force. The fuel metering force is set up across a diaphragm. On one side of the fuel diaphragm, there is metered fuel pressure, which is regulated by the discharge nozzle. On the opposite side of the fuel diaphragm, there is unmetered fuel pressure, which is regulated by the opening of the poppet valve. The air metering force will then regulate the fuel metering force in proportion to the mass airflow through the throttle body.

The air diaphragm separates chambers "A" and "B." The air metering force is set up across this diaphragm.

The fuel diaphragm separates chambers "C" and "D." The fuel metering force is set up across this diaphragm.

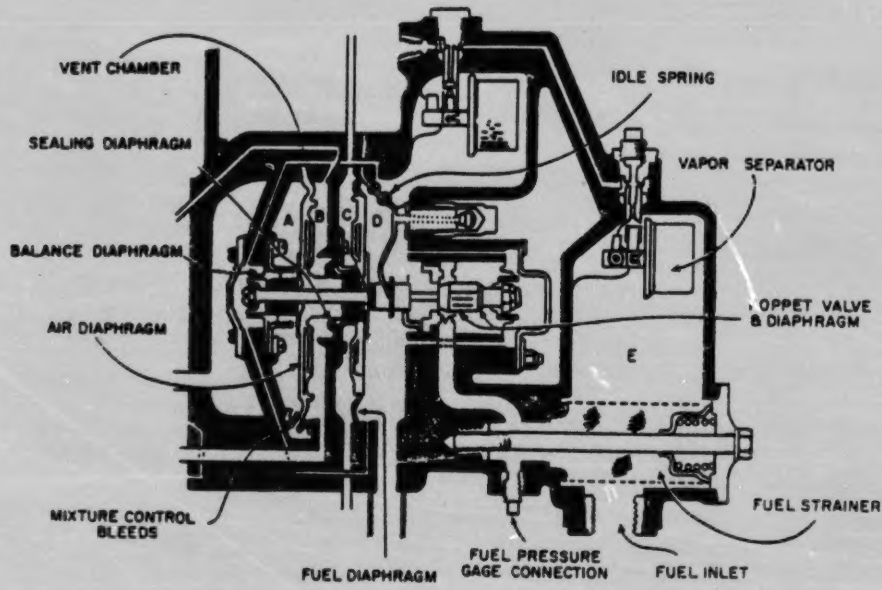

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Figure 7-5.–Regulator unit.

Chambers "A" through "E":

1. Chamber "A" is regulated impact pressure.
2. Chamber "B" is boost venturi pressure.
3. Chamber "C" is metered fuel pressure, controlled by the discharge nozzle.
4. Chamber "D" is unmetered fuel pressure, controlled by the opening of the poppet valve.
5. Chamber "E" is fuel pump pressure, controlled by the pressure relief valve on the fuel pump.

The poppet valve is attached by its stem to both the fuel and air diaphragms. A sealing diaphragm, is located between "B" and "C" chambers to seal metered fuel pressure from boost venturi suction.

The balance diaphragm balances out the action of the sealing diaphragm.

The single faced poppet valve has a diaphragm to balance out fuel drag on the poppet valve.

The vapor separator located in "D" and "E" chambers are float and needle valve arrangements which permit vapor formed in the carburetor to return to the fuel tank.

The mixture control bleeds are in a passage between chambers "A" and "B," and they provide for a circulation of air through these chambers to make the AMC unit effective.

The carburetor fuel strainer is a fine mesh screen located in the inlet to "E" chamber through which all the fuel must pass as it enters "D" chamber. The strainer must be removed and cleaned on all periodic inspections.

FUEL CONTROL UNIT.–The purpose of the fuel control unit is to meter and control the fuel flow to the discharge nozzle. The basic unit consists of three jets and four valves that are arranged in series, parallel, and series-parallel hookups. (See fig. 7-6.) These jets and valves receive fuel under pressure from the regulator unit and then meter the fuel as it goes to the discharge nozzle. The manual mixture control valve controls the fuel flow. By the use of proper size jets and regulating the pressure differential across the jets, the right amount of fuel is delivered to the discharge nozzle, giving the desired air-fuel ratio in the various power settings. It should be remembered that the inlet pressure to the jets is regulated by the regulator unit and the outlet pressure is controlled by the discharge nozzle.

The jets in the basic fuel control unit are the auto lean jet, the auto rich jet, and the power enrichment jet. The basic fuel supply is the fuel required to run the engine with a lean mixture and is metered by the auto lean jet. The auto rich jet adds enough fuel to the basic flow to give a slightly richer than BEST POWER mixture when the manual mixture control is the AUTO RICH position. The power enrichment jet limits the amount of fuel that can be added to the auto lean jet in the late power range.

The four valves in the basic fuel control unit are the idle valve, the power enrichment valve, the regulator fill valve, and the manual mixture control. These valves and their functions are as follows:

1. The idle valve is a round, contoured needle valve or a cylinder valve placed in series with all other metering devices of the basic fuel control unit. It is connected by linkage to the throttle shaft in such a way that it will restrict the fuel flowing at low-power settings (idle range). The idle valve meters the fuel in the idle range only.
2. The manual mixture control is a rotary disk valve consisting of a round stationary disc with ports leading from the auto lean jet, the auto rich jet, and two smaller ventholes. Another rotating port, resembling a cloverleaf, is held against the stationary disc by spring tension and rotated over the ports in that disc by the manual mixture control lever. All ports and vents are closed in the IDLE CUTOFF position. In auto lean position, the ports from the auto lean jet and the two ventholes are open. The port from the auto rich jet ramains closed in this position. In the auto rich position, all ports are open. From this it can be seen that there are three positions of the manual mixture control lever which enable the pilot to select a lean mixture or a rich mixture, or to stop fuel flow entirely. The idle cutoff position is used only for starting or stopping the engine. Fuel for starting is supplied by the primer.
3. The regulator fill valve is a small poppet type valve located in a fuel passage which supplies chamber "C" of the regulator unit with metered fuel pressure. In idle cutoff, the flat portion of the cam lines up with the valve stem and a spring closes the valve. This provides a

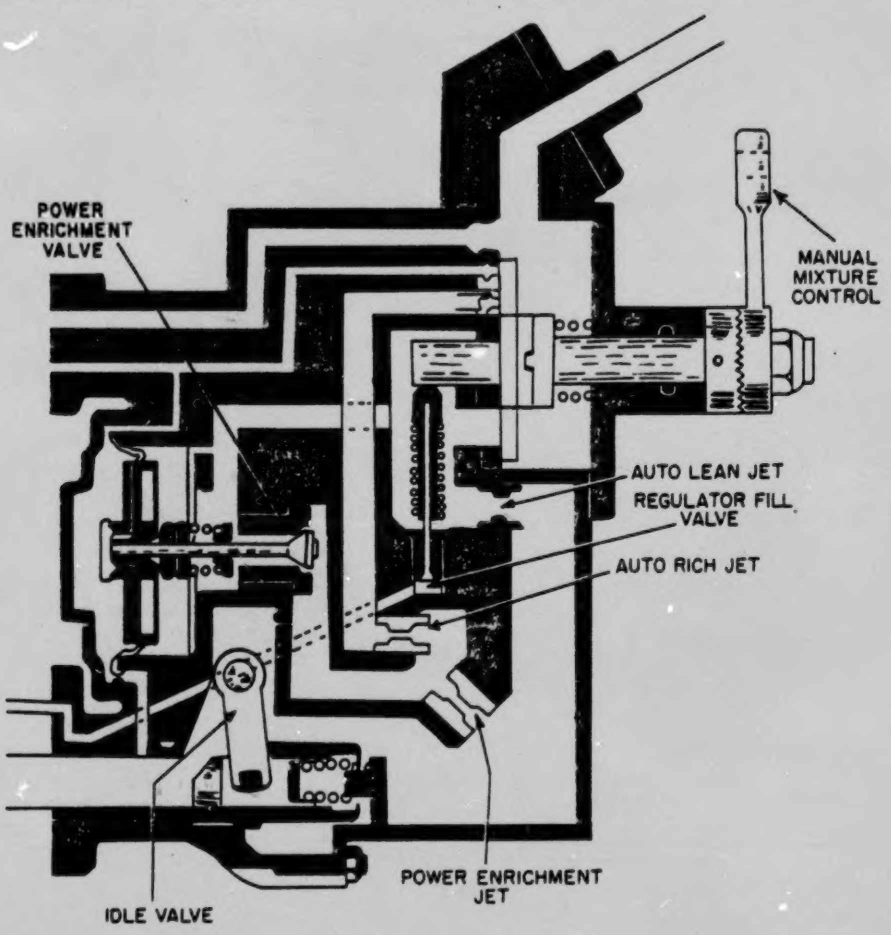

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Figure 7-6.–Fuel control unit.

means of shutting off the fuel flow to chamber "C" and thereby provides for a positive idle cutoff.

4. The power enrichment valve is another poppet type valve. It is in parallel with the auto lean and auto rich jets, but it is in series with the power enrichment jet. This valve starts to open at the beginning of the early power range. It is opened by the unmetered fuel pressure overcoming metered fuel pressure and spring tension. The power enrichment valve continues to open wider and wider through the power range until the combined flow of the valve and the auto rich jet exceeds that of the power enrichment jet. At this point the power enrichment jet takes over the metering and will meter fuel on through the late power range.

5. Carburetors equipped for water injection are modified by the addition of a derichment valve and a derichment jet.

The derichment valve and derichment jet are in series with each other and parallel with the power enrichment jet. In the late power range, the derichment jet and the power enrichment jet deliver the same quantity of fuel as the power enrichment jet installed in the basic carburetor.

ADAPTER.–The purpose of the adapter is to adapt the carburetor to the engine. This unit may also contain the discharge nozzle and the accelerating pump. (See fig. 7-7.) On engines using fuel feed valves, however, the discharge nozzle is eliminated, since the fuel feed valve serves the same purpose and is built into the engine. Where a spinner injection discharge valve is used in place of the discharge nozzle, the accelerating pump is usually housed on the side of the throttle body, and the adapter is then nothing more than a spacer and has no working parts.

The discharge nozzle is a spring-loaded valve which maintains metered fuel pressure. Before fuel can pass through the discharge nozzle, enough pressure must be built up against the diaphragm to overcome the tension of the spring which is on the air side of the diaphragm. The diaphragm then rises, lifting the attached valve, and the fuel is sprayed out the nozzle. Secured to the nozzle is a diffuser which is designed to improve distribution and atomization of the fuel into the airstream. There are three types of diffusers used in adapter-mounted discharge nozzles–the rake, the bar, and the bow tie. Two other diffusers built into some engines are the slinger ring used with the fuel feed valve and the spinner ring used with the spinner injection discharge valve.

The acceleration pump is used to compensate for the inherent lag in fuel flow during rapid acceleration of the engine.

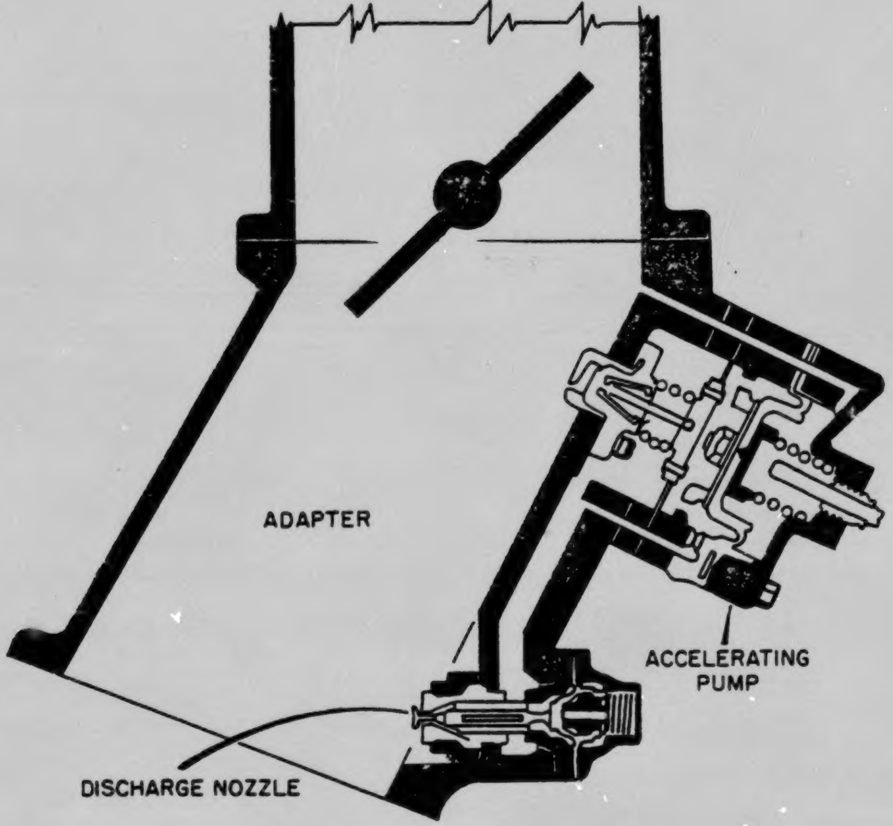

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Figure 7-7.–Adapter.

CARBURETOR REMOVAL

The removal procedures will vary with both the type of carburetor concerned and the type of engine on which it is used. The ADR must always refer to the applicable technical instructions concerning the installation on which he is working. The general procedures will be much the same, regardless of the type of carburetor concerned. Some general precautions are listed below.

Make sure the fuel shutoff (or selector) valve is in the closed position. Disconnect the throttle and mixture control linkages, lockwire the throttle valve in the closed position; disconnect the fuel inlet line and all vapor return, gage, and primer lines. Figure 7-8 illustrates the installation connection points on a typical carburetor.

If the same carburetor is to be reinstalled, do not alter the rigging of the throttle and mixture controls. Disconnect the airscoop, or airscoop adapter, at the carburetor top deck. Remove the air screens and gaskets from the top of the carburetor. Remove the nuts and washers securing the carburetor to the engine. Using extreme care to insure that nothing is dropped into the impeller, remove the carburetor. Install a protective cover on the carburetor mounting flange of the engine immediately, to prevent small parts of foreign material from falling into the supercharger passages.

CARBURETOR INSTALLATION

The procedures discussed in this section are based on a typical pressure injection carburetor.

Remove the pipe plugs from the bottom of the carburetor and allow the flushing oil, if present, to drain from the carburetor. The draining may be hastened by removing the fuel strainer and the plug in the fuel inlet. Also, remove the plug in the vapor vent outlet. When all oil has drained from the carburetor, replace the fuel strainer and plugs.

Place the manual mixture control lever in the AUTO RICH position and the throttle lever in the OPEN position.

Fill the carburetor with fuel of the type to be used in service operation. This can be accomplished by injecting the fuel through the regular carburetor fuel inlet, continuing the flow until oil-free fuel flows from the discharge

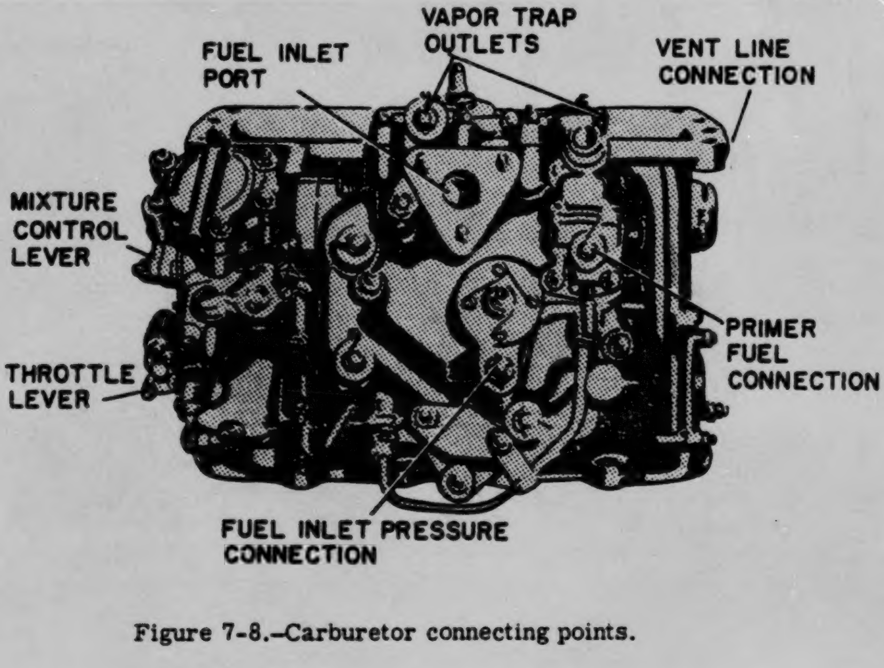

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Figure 7-8.—Carburetor connecting points.

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nozzle or from the fuel outlet on the fuel control unit, if the fuel transfer tube is not installed at this time. During the flushing procedure, actuate the throttle valve and the mixture control lever.

Turn off the fuel flow, plug the fuel inlet and vapor vent outlet, and then allow the carburetor, FILLED WITH FUEL, to stand for a minimum of 8 hours before being used on an engine. This is necessary in order to soak the diaphragms and render them pliable to the degree they were when the unit was originally calibrated.

Check the carburetor for proper lockwiring before installation on an engine.

Remove the protective cover from the carburetor mounting flange on the engine. Place the carburetor mounting flange gasket in position. On some engines, bleed passages are incorporated in the mounting pad. The gasket must be installed so that the bleed hole in the gasket is alined with the passage in the mounting flange. Be certain the opening to the metered fuel passage is free of foreign matter and a new fuel seal gasket is installed.

Inspect the induction passages for the presence of any foreign material before installing the carburetor. Install the carburetor on the mounting pad and gasket; install the attaching capscrews and tighten them to the proper torque value; then secure the screws with lockwire.

Place the carburetor air screen lower gasket, the air screen, and the air screen upper gasket in position on the top face of the carburetor. Mount the carburetor header, or the carburetor airscoop adapter, on the carburetor. Reinstall the fuel transfer tube, if used, and attach all lines, electrical cables, and control linkages.

WATER INJECTION

Some aircraft, such as the SP-2H, have engines that are equipped with water injection systems.

The water injection system enables the pilot to obtain more power from the engine, at takeoff or during emergency situations in the air, than is possible under normal operating conditions. The carburetor, under normal operating conditions at high-power settings, delivers more fuel to the engine than the engine actually needs. This excess fuel is used to carry off heat that is developed in the cylinders during the combustion process and is scavenged with the exhaust gases.

The carburetor is equipped with a derichment valve, which reduces the amount of fuel being furnished by the carburetor to the engine. The derichment valve, when actuated by the water pressure, shuts off the fuel being delivered through the derichment jet, eliminating the extra fuel normally used for cooling. At the same time the water-alcohol mixture is delivered downstream of the carburetor in the blower throat and mixed with the air/fuel mixture. The addition of the water-alcohol into the induction system and the vaporization of the fluid then supplies the cooling formerly provided by the excess fuel.

Water injection produces its effects by cooling the air/fuel charge, thus increasing the charge density; by direct cooling of the piston and cylinder, permitting the use of higher BMEP without the danger of detonation; and by permitting the use of leaner, best power mixtures.

The water injection system of the SP-2H aircraft is composed of the following components. The engines are equipped with an individual system of a water tank, strainer, tank drain valve, water pump (similar to the engine-driven fuel pump but have carbon vanes instead of steel vanes), power control unit, control switch, and a circuit breaker.

WARNING: The water injection fluid is composed of distilled water and METHYL ALCOHOL. The FLUID IS A DEADLY POISON, for which there is no known antidote. The vapors of the fluid, if inhaled in sufficient quantities, will have the same effect as if the fluid were taken internally.

DIRECT FUEL INJECTION

In the direct fuel injection system, air alone, rather than a fuel/air mixture, enters the cylinder through the intake port. The liquid fuel is injected directly into the combustion chamber.

The direct fuel injection system has many advantages over the carburetor system. When the fuel is discharged directly into the cylinder, the engine starts more readily. With air, instead of an explosive mixture, in the induction system, backfiring is practically impossible. In a direct injection system, there is less danger of induction system icing, since the drop in temperature caused by vaporization of the fuel takes place within the cylinder. Acceleration is improved also because of the positive action of the injection equipment. In addition, direct fuel injection improves fuel distribution and reduces the overheating of individual cylinders often caused by variation in mixture strength due to uneven fuel distribution. The fuel injection system also gives better fuel economy than a system in which the mixture flowing to the majority of cylinders must be made richer than necessary in order that the leanest cylinder will receive a sufficiently rich mixture.

The direct fuel injection system of the R-3350-34 and -42 engine consists of a master control (carburetor) for metering the fuel; a fuel flow divider; two engine-driven injection pumps, which divide and distribute the metered fuel; distribution lines; and an injection nozzle in each cylinder.

Master Control

The master control is mounted on the engine in the position otherwise occupied by the carburetor. This unit measures the airflow and meters the corresponding volume of fuel to the injection pumps. The master control is essentially the same as the injection carburetor except that the metered fuel is directed to the injection pumps instead of being discharged into the induction system.

Pumps

The two injection pumps are mounted on pads on each side of the supercharger rear housing, just below the master control. The pump on the right side serves the front row of cylinders; the pump on the left side serves the rear row of cylinders. Each pump contains nine plungers, which divide and distribute the fuel (metered by the master control) to the combustion chambers of the engine cylinders. Each plunger feeds one cylinder exclusively.

Metered fuel from the master control is directed through a fuel flow divider to the two injection pumps. Each of the pumps receives an equal amount of the fuel from the master control. An adapter which is timed to the engine provides for the mounting of each pump. The splined drive shaft of the pump has a master spline, so that the pump can be mounted on the adapter in only one position. The pump adapters are timed to the engine crankshaft, so that the cylinder receives the fuel charge at the correct moment in relation to piston position and the ignition event.

Fuel Injection Nozzles

A fuel injection nozzle (fig. 7-9) is mounted in the front of each cylinder. The nozzle is composed of the following parts—body, valve, valve spring and seat, an adjusting nut, and a packing seal. When the pressure in the fuel injection line reaches approximately 500 psi, the valve within the injection nozzle is unseated and the fuel is forced into the cylinder. The valve stem within the nozzle incorporates an augerlike section which causes the fuel to swirl as it leaves the nozzle. This is to aid the atomization of the fuel as it enters the cylinder.

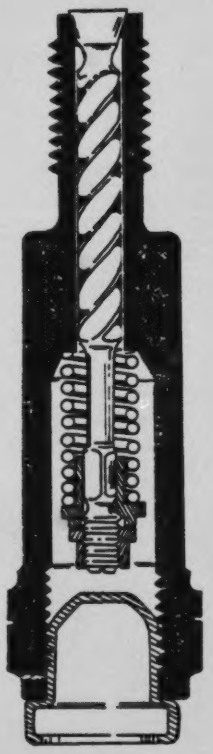

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Figure 7-9.—Fuel injection nozzle.

No repairs of the nozzle or adjustments are permitted in the field. If malfunctions occur in the operation of a nozzle, it must be replaced with a new or overhauled nozzle and the defective one must be turned in to be overhauled or scrapped.

FUEL SYSTEM MAINTENANCE

Maintenance of the aircraft and engine fuel system is the responsibility of the ADR. This includes the entire system except repairs to bladder and self-sealing cells and integral fuel tanks, which are the responsibility of personnel of the AM rating.

Location of fuel system leaks along with general maintenance procedures and the rigging and adjusting of the various fuel system controls are discussed in the following paragraphs.

NOTE: Safety around fuels cannot be overemphasized. Therefore, when any maintenance is performed on or around aircraft fuel systems, all safety precautions must be strictly complied with.

LOCATION OF LEAKS

The use of internal lines, fittings, and fuel activating devices in aircraft fuel systems presents a problem in determining the location of fuel leaks. The most practical method consists of adding a concentrated solution of a fuel soluble red dye to the aircraft fuel tank and waiting for the dye to appear in leaking fuel.

A liquid red dye is available which can be added directly to the aircraft fuel tank. (Before the dye is used to determine the source of fuel leaks, any visible fuel leaks in the tanks and plumbing must be eliminated.) If it is necessary to use dye to locate a hidden leak, select a method for filling the fuel tanks that will allow the testing of only one questionable tank at a time. Add the liquid red dye to the suspected tank when it is one-quarter full, using a full 2-ounce can of red dye for each 100 gallons of tank capacity; rinse the can with fuel.

NOTE: Never use more than one 2-ounce can of red dye for each 100 gallons of fuel.

Completely fill the tank with fuel after adding the dye and wait for signs of coloration from the leaking fuel. A very small leak may require an hour or more for color to appear. If no coloration appears after a reasonable waiting period, repeat the process on other tank units until the leak is located. The dye will leave a stain which can be traced back to the source of the leak even after the tank unit has been emptied and the drippage has ceased.

NOTE: Do not return the colored fuel to bulk storage tanks or trucks, as there is sufficient dye in a 2-ounce can to color 10,000 gallons of fuel.

The colored fuel is suitable for use in aircraft engines inasmuch as the dye does not have a harmful effect on the usefulness of the fuel. If it is not necessary to empty the aircraft fuel tank to repair the leak, the dyed fuel may be burned in the engine. Fuel from tanks tested with dye will remain colored until the tanks have been filled and emptied several times. Stains on the aircraft structure or clothing can be removed with aircraft fuel or an approved drycleaning solvent.

NOTE: When this method of leak detection is used, an entry is required in the Aircraft Logbook so that the user of the aircraft will be aware that the fuel color results from the use of the dye and should be disregarded in daily fuel analysis.

Pumps

Check boost pumps for proper operation and correct pressure output. Check for leaks and for condition of fuel and electrical connections. Be sure that the drain lines are free of traps, bends, and restrictions. Check the motor brushes for wear.

MAIN-LINE STRAINER

Drain water and sediment from the main-line strainer at each preflight inspection. Remove and clean the screen at the periods specified in the applicable technical publications. Examine the sediment removed from the housing. Particles of rubber are often early warnings of deterioration of hose or self-sealing tanks. Check for leaks and damaged gaskets.

FUEL LINES AND FITTINGS

Be sure that the lines are properly supported and that the nuts and clamps are securely tightened. To tighten hose clamps to the proper torque, use a hose-clamp torque wrench. If this wrench is not available, tighten the clamp finger-tight plus the number of turns specified for the hose and clamp. Tighten clamps only when the engine is cold. If the clamps do not give a seal at the specified torque, replace the clamps, the hose, or both. After installing new hose, check the hose clamps daily and tighten if necessary. When this daily check indicates that cold flow has ceased (cold flow is the flowing of the rubber from the clamping area), inspect the clamps throughout the system. Replace the hose if the plies have separated, if there is excessive cold flow, if there are signs of chafing, or if the hose is hard and inflexible. Permanent impressions from the clamps and cracks in the tube or cover stock indicate excessive cold flow. Replace hose which has collapsed at the bends or as a result of misaligned fittings or lines if there is any doubt of its serviceability. Some hose tends to flare at the ends beyond the clamps. This is not an unsatisfactory condition and does not indicate leakage. Inspect all hose connections forward of the firewall at each engine change, and replace all defective hose.

SELECTOR VALVES

Rotate selector valves and check for free operation, excessive backlash, and accurate pointer indication. If the backlash is excessive, check the entire operating mechanism for worn joints, loose pins, and broken drive lugs. Replace any defective parts in the operating mechanism. Inspect cable control systems for worn or frayed cables, damaged pulleys, and worn pully bearings.

REPLACEMENT OF GASKETS, SEALS, AND PACKINGS

In order to prevent leakage of fuel, it is of utmost importance that all gaskets, seals, and packings be properly installed. Listed below are some of the general precautions which should always be observed.

When replacing units of the fuel system, it is necessary to check each part for cleanliness, insure that all of the old gasket material is removed, and insure that none of the old seal remains in the groove seat. Always replace old gaskets and seals with new components, check the new gaskets and seals for cleanliness, and integrity, and insure that it is the right part for the job. Mating surfaces should be perfectly flat so that the gasket can do the job for which it is designed. Screws, nuts, and bolts that retain units together should be evenly tightened or torqued to prevent leakage past the gasket or seal in the unit.

RIGGING AND ADJUSTING

This section covers some of the basic procedures and inspections to be used in the rigging and adjusting of throttles, mixture controls, fuel selectors, firewall shutoff valves, fuel pressure, idle mixture, and idle rpm. Adjustmentsof the idle mixture, fuel pressure, and idle rpm are general in nature and are discussed first. The EC-121K is used as a typical aircraft for the purpose of rigging and adjusting throttles, mixture controls, fuel selectors, and firewall shutoff valves. These procedures are given only to acquaint the ADR with the rigging and adjusting procedures and should not be used for actually rigging the controls on the aircraft.

FUEL PRESSURE

In order to maintain the correct fuel pressure delivery to the carburetor or master control, the engine-driven fuel pump has a relief valve screw which can be adjusted to the proper amount of pressure. This screw sets the spring tension on the relief valve to relieve the pressure on the "out" side of the pump whenever the pump output exceeds the amount needed by the carburetor. (See fig. 7-2.) The excess fuel is thus bypassed back to the inlet side of the pump. The pump also contains a bypass valve that allows fuel under pressure from an auxiliary pump to pass through the engine-driven pump when it is not operating. If the pressure at the discharge side of the pump exceeds that for which the relief valve is set, the valve is raised from the valve seat against the pressure of the relief valve spring. Fuel then passes through the opening thus made and back to the inlet side of the pump.

The bypass valve is held closed by pressure of the fuel and a small spring when the engine-driven pump is in operation. When the engine-driven pump is inoperative, and fuel is forced through the pump by an auxiliary pump, the fuel enters the pump at the usual inlet, but is prevented from passing directly to the outlet port by the stationary vanes, and therefore goes through the bypass valve to the outlet port and to the carburetor.

IDLE MIXTURE

If, in making the idle mixture check, the manifold pressure rises directly from the stabilized value, the idle mixture is not excessively rich, but may be richer than a "rich best-power" setting. In this case, turn the knurled mixture-adjusting screw, located on the left side of the carburetor, about four notches CLOCKWISE toward RICH. Repeat the mixture check with the control lever. If the manifold pressure does not now indicate an excessively rich mixture, enrich the mixture until this indication is obtained. The adjustment is shown in figure 7-10.

After the desired rich indication is obtained, lean the mixture, one notch at a time, until a point is reached where the manifold pressure rises directly from its stabilized value. This is the rich best-power setting.

Allow the engine to operate at idling speed for several minutes until the cylinder head temperature stabilizes at the minimum value. Reset the idle speed stops for the desired idling speed.

It is possible that the knurled adjusting screw will not provide a sufficient range of adjustment to permit obtaining the desired idle mixture setting. In this case, the idle link must be disconnected and the screw eye screwed in or out of the threaded bushing. Screw it IN to lean the mixture and OUT to enrich the mixture. One revolution of the screw is equivalent to approximately 13 notches of adjusting screw rotation on Stromberg

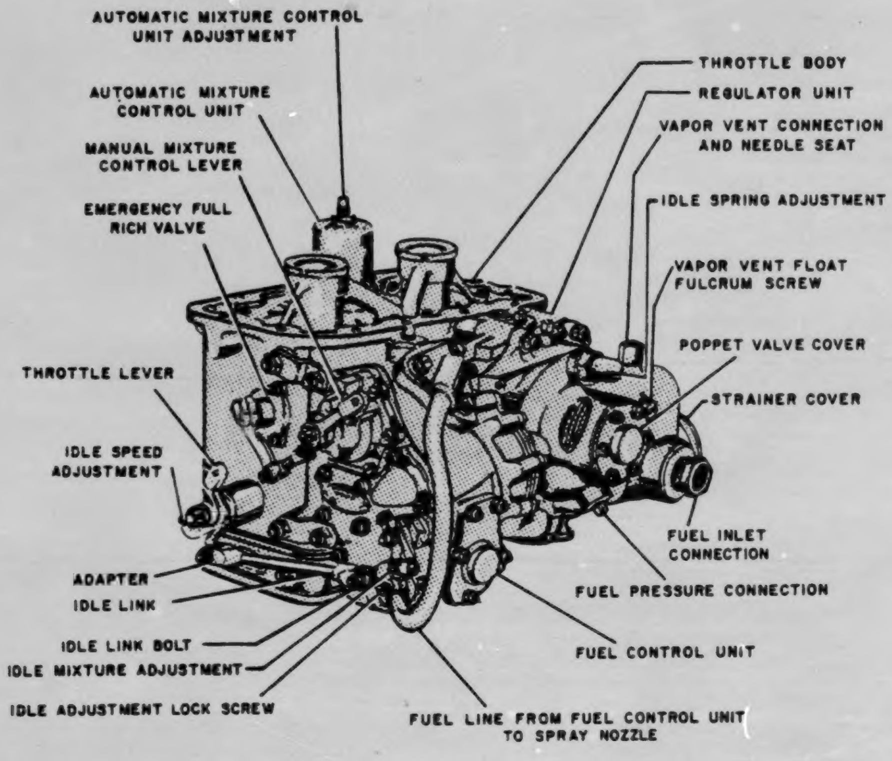
AUTOMATIC MIXTURE CONTROL UNIT ADJUSTMENT
AUTOMATIC MIXTURE CONTROL UNIT
MANUAL MIXTURE CONTROL LEVER
EMERGENCY FULL RICH VALVE
THROTTLE LEVER
IDLE SPEED ADJUSTMENT
ADAPTER
IDLE LINK
IDLE LINK BOLT
IDLE MIXTURE ADJUSTMENT
IDLE ADJUSTMENT LOCK SCREW
FUEL LINE FROM FUEL CONTROL UNIT TO SPRAY NOZZLE
THROTTLE BODY
REGULATOR UNIT
VAPOR VENT CONNECTION AND NEEDLE SEAT
IDLE SPRING ADJUSTMENT
VAPOR VENT FLOAT FULCRUM SCREW
POPPET VALVE COVER
STRAINER COVER
FUEL INLET CONNECTION
FUEL PRESSURE CONNECTION
FUEL CONTROL UNIT

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Figure 7-10.–Pressure injection carburetor nomenclature and adjustments.

carburetors and master controls. A cutaway view of this linkage is shown in figure 7-11.

IDLE RPM

If the rpm obtained with the throttle at the idle position differs from the idle rpm specified in the Service Instructions Manual (usually 600 rpm on an engine equipped with exhaust stacks and 450 rpm on an engine equipped with collector rings), reset the idle rpm stop. The engine must be warmed up thoroughly and checked for ignition system malfunctioning, as described previously. Throughout any carburetor adjustment procedure, run the engine up periodically to approximately half of normal rated speed to clear the engine.

With the engine idling, turn the eccentric screw in either direction from the lowest setting to increase rpm. Adjust the eccentric screw as required to increase or decrease rpm. Open the throttle to clear out the engine; close the throttle, and wait for the rpm to stabilize. Repeat this operation until the desired idling speed is obtained.

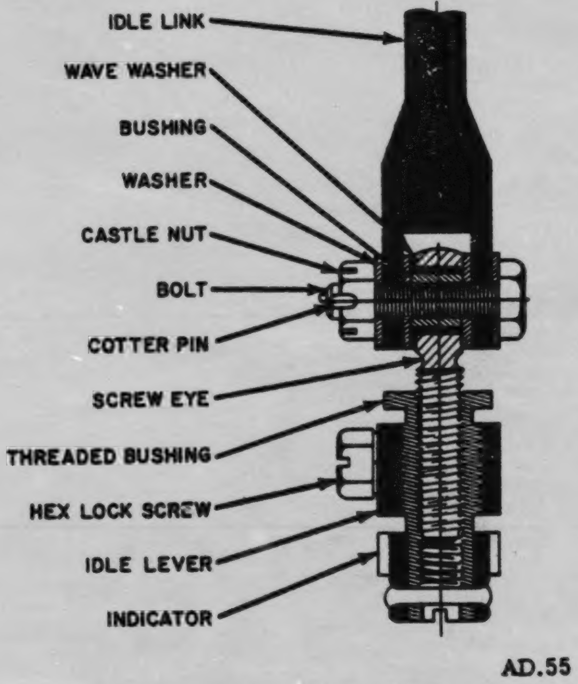

Figure 7-11.–Idle mixture adjustment linkage.

NOTE: As previously stated, the EC-121K is used as a typical installation for the following discussion. Prior to attempting to rig or adjust any controls, the following inspection should be accomplished.

Inspect all bellcranks, cables, and rod bearings for looseness, cracks, and corrosion. Particular attention should be given the rod and bellcranks where the bearing is staked. This area is subject to stress cracking and corrosion. The adjustable rod ends should be inspected for damaged threads and the number of threads remaining after final adjustment. The drums should be inspected for wear, and the cable guards should be checked for proper position. If the cables have been loosened, the tension must be set.

THROTTLE

The throttles are actuated by cable systems which extend from the flight station to the firewall in each nacelle. Levers for each throttle system are located on the pilot's control stand and the flight engineer's control stand. The controls that are forward of the firewall consist of a pulley mounted in a swinging bracket supported by the nacelle structure, and two parallel rods extending from the pulley to a double-armed bellcrank on the master control throttle shaft. The swinging bracket will compensate for engine vibration and movement so that the throttle settings will not be affected. To rig the throttle control, proceed as follows:

1. Install a rigging pin in the firewall pulley and its bracket.
2. Adjust the push-pull rods between the firewall pulley and the master control so that the throttle shaft is resting firmly against the closed stops and the pulley shaft center on the swinging bracket is the correct number of inches from the firewall.
3. Then adjust the cable tension in the system to the proper tension so that the pilot's throttle lever has the correct amount of cushion in the closed position.
4. While maintaining the position of the pilot's lever, adjust the turnbuckles at the flight engineer's control stand so that the flight engineer's lever will have the correct amount of cushion.

5. Recheck the cable tension, the throttle shaft position, and the position of both throttle levers in the cockpit.

6. Then remove the rigging pin and check the throttle lever from both positions in the cockpit several times to ascertain that there is a full freedom of movement.

MIXTURE CONTROL LINKAGE

The mixture control on the master control is cable operated from the flight engineer's control stand to a pulley mounted on a swinging bracket on the overhead of the nacelle structure forward of the firewall. The bellcrank on the mixture control rod is connected to this pulley by a push-pull rod. The swinging bracket assembly performs the same function here as the swinging bracket assembly performs for the throttle.

The rigging of the mixture control is as follows:

1. Install a rigging pin in the firewall pulley and bracket.

2. The mixture control lever on the master control is to be placed in the IDLE CUTOFF position.

3. The push-pull rod between the master control and the swinging bracket on the firewall should be adjusted until the swinging bracket is the proper distance from the firewall. When this is done, slip the bellcrank onto the mixture control and then tighten it down against the serrations.

NOTE: Observe the precautions of adjusting the rod end assembly so that it has sufficient thread engagement.

4. Adjust the cable portion of the linkage so that the control lever in the cockpit is in the IDLE CUTOFF position. Then tighten the cables to the proper tension.

5. Remove the rigging pin and then operate the system through the full range of travel several times to insure that the mixture control plates are in the proper position in relation to the lever at the flight engineer's panel.

FUEL SELECTOR

The fuel tank selector and shutoff valves are cable operated from the flight engineer's control stand. To rig them, proceed as follows:

1. Place the flight engineer's control levers in the CLOSED position for the valves to Nos. 1, 4, and 5. The three-way selector valve control levers are to be placed in the midtravel position, or in the No. 2 and No. 3 positions, respectively.

2. Adjust the cable tension to the proper amount so that the control levers to Nos. 1, 4, and 5 have the proper amount of cushion in the CLOSED position. Remove the rigging pin and check for the proper amount of cushion when the levers are moved to the OPEN position. While the three-way selector valve control levers are in the MID position, check for the proper amount of tension on the cables.

NOTE: All cable tension adjustments should be made in relation to temperature.

3. Recheck all cable tensions, position of the control levers, and the position of the valve actuating levers. Also check for smoothness of operation throughout the operating range.

FIREWALL SHUTOFF VALVES

The four emergency fuel shutoff valves are located upstream from the engines. These are manually operated two-way valves and operate in conjunction with the blast air, oil, and hydraulic emergency shutoff valves. They are controlled from the overhead control panel in the flight station. The rigging procedure is as follows:

1. Insert pin in the pulley rigging hole.

2. Place valve lever in the OPEN position.

3. Place the flight station emergency shutoff lever in the OPEN position.

4. Adjust the push-pull rod to the proper length and install on the valve lever. Make final adjustment as necessary to the rod for the proper alignment of the levers.

5. Operate the flight station lever to the OPEN and the CLOSED position to check the proper operation of the valve.

CHAPTER 8

RECIPROCATING ENGINE LUBRICATING SYSTEMS

The ADR must be familiar with the lubricating system of aircraft engines, including oil tanks, oil coolers, temperature controls, and strainers. He should know the operating characteristics of the system, particularly the oil flow and the oil temperature. This knowledge will aid in obtaining the optimum performance, in terms of reliability and durability, from the engine.

AVIATION LUBRICATING OIL

Oil is the lifeblood of the aircraft engine. If the oil supply to the bearings should cease, within a matter of seconds the lubricating films would break down and cause scoring, seizing, and burning of the vital moving parts. Fortunately, the engine oil pump and oil system are dependable and, like the heart and circulatory system of the human body, quietly perform their function so well that their importance is often forgotten.

OIL QUALITY REQUIREMENTS

For proper lubrication of the aircraft engine, the lubricating oil must meet several very important requirements.

The conditions in both reciprocating and turbojet engines are so varied that one lubricant could scarcely be expected to produce ideal lubrication conditions on all bearing surfaces. However, satisfactory results are obtained in a well-designed engine with a lubricating oil having all the desirable properties in varying degree.

Viscosity

The internal friction of the oil, or its resistance to flow, is known as viscosity. The degree of cohesion (sticking together) between the molecules of an oil determines its viscosity. (Molecules are the smallest units of matter that retain chemical identity with the substance in mass.) Thus, the molecules of the more viscous (high viscosity) oils bind themselves together with far greater force than that existing in lower viscosity oils where the bond of force between molecules is much weaker.

Antifriction

The lubricant should have high antifriction characteristics to reduce the frictional resistance of the moving parts when separated only by thin oil films. An ideal fluid lubricant provides a strong oil film to prevent metal-to-metal contact and to create a minimum amount of oil friction or oil drag.

Lubricants should have the property of resisting the wiping action that occurs wherever microscopic films are used to prevent metallic contact. The theory of fluid lubrication is based on the actual separation of the metallic surfaces by means of an oil film. As long as the oil film is not broken, the internal friction, or fluid friction, of the lubricant takes the place of the metallic sliding friction which otherwise would exist between the parts.

Chemical Stability

A lubricant should offer the maximum resistance to the formation of harmful deposits on the metal parts. It should not attack or injure metals in the lubricated parts.

Cooling

One reason for using liquid lubricants is that they can be readily pumped or sprayed.

Regardless of the method of application, the oil absorbs the heat and later dissipates it through cooling devices. Many engine parts, especially those carrying heavy loads at high rubbing velocities, are lubricated by oil under direct pressure. Where direct pressure lubrication is not practical, a spray or mist of oil provides the required protection.

FUNDAMENTALS OF LUBRICATING OIL

Lubrication in its various forms serves five purposes. They are as follows:

1. Reducing friction.
2. Cooling the engine.
3. Sealing various clearances in the engine.
4. Preventing corrosion.
5. Cleaning the engine.

Friction Reduction

Friction (resistance to relative motion between two bodies) produces heat. In aircraft engines, it is imperative that this friction and heat be kept to a minimum. The presence of a lubricating film between moving parts serves this purpose. Due to its adhesive qualities, the lubricant sticks to the moving solids. The force which tends to hold the lubricant particles together is known as cohesive quality. The lubricant tends to separate into layers in such a manner that the resultant friction is that produced between the layers of lubricant rather than between the two solids.

Cooling

As the oil is circulated through the bearings and splashed or sprayed on the various engine parts, it absorbs a great amount of heat. The heat produced by friction and by the combustion process must be reduced and controlled. Thus, oil cooling is an important factor in keeping the engine temperature within the proper limits and is particularly important in cooling the pistons and cylinders of reciprocating engines.

As the oil is pumped through the engine, the temperature of the oil is greatly increased by absorbing heat from the engine. The oil then carries the heat off to the oil coolers where it is dissipated.

Sealing

The oil film on the various surfaces also acts as an effective pressure seal particularly between piston, piston rings, and cylinder wall. The oil film also aids in sealing the various parting surfaces between various sections of the engine.

Corrosion Preventive

A film of oil over the metal surfaces isolates the surfaces from the atmosphere and combustion fumes, and aids in corrosion prevention.

Cleaning

As the oil is pumped through the bearings and flows over the various engine parts, it picks up various impurities and carries them through the oil system to the strainer where they are filtered from the oil stream. The impurities may include the following: Lead and carbon particles produced by combustion, water, dust from the atmosphere, and metal particles from worn or defective engine parts.

TYPES OF LUBRICANTS

Lubricants may be classified by types according to their source or origin. ANIMAL OILS are not suitable lubricants for internal-combustion engines, because they form fatty acids, which will cause corrosion when exposed to high temperatures. VEGETABLE OILS have good lubricating qualities, but break down (i.e., change in chemical structure) when subjected to long periods of operation in internal-combustion engines. MINERAL-BASED LUBRICANTS are usually divided into three groups: Solids, semisolids, and liquids.

Solids

Solids include mica, soapstone, and graphite. Graphite, when in powdered form, serves to fill the low spots in bearing surfaces to form a smoother antifriction surface. Solid lubricants do not dissipate heat rapidly consequently, their use is restricted to low-temperature conditions.

Semisolids

Semisolids are greases of the type used for steel bearings. They give excellent service provided they are changed periodically.

Liquids

Liquids are used as lubricants for internal-combustion engines. They may be pumped or sprayed, they provide good cushioning, they are effective in absorbing and dissipating heat, and they remain chemically stable over long periods of time under normal operating conditions.

CLASSIFICATION OF LUBRICATING OILS

Aircraft engine lubricating oils are classified as listed in table 8-1.

NOTE: All Navy and Marine Corps reciprocating engines use a single grade of ashless dispersant type oil purchased under Specification MIL-L-22851, Type II. This is basically a grade 1100 oil with additives to improve oxidation resistance, to hold in suspension sludge and varnish forming particles, and to reduce foaming tendencies. The additives do not form ash when burned and therefore will not contribute to spark plug fouling deposits. Standard oil dilution procedures can be used with this type oil during cold weather operations without hazard of excessive sludge breaking loose in the engine, which can occur when using a nonadditive type oil.

Cold weather operation often causes engine oil-inlet temperature to drop below the minimum required for evaporation of the products of combustion (water and partially burned fuel) which blow past the piston and condense in cold oil. Operating an engine for an extended period of time below 60° C (140° F) may result in a buildup of a water emulsion in the oil, which can contribute to the precipitation of sludge that would normally be held in suspension by the dispersant additives in MIL-L-22851 oil. All engine turnups should be performed long enough for the oil temperature to stabilize at the level specified in the applicable Aircraft NATOPS Flight Manual and for at least 10 additional minutes in order to boil off any water that may have condensed in the oil.

The dispersant oil, specification MIL-L-22851, is basically a grade 1100 oil, as mentioned before. The commercial dispersant type oils, which are essentially equivalent to MIL-L-22851 oils, are available and are identified as AeroShell oil W-100 or W-120 and Humble/Esso oil E-100 or E-120.

FACTORS AFFECTING TRANSMISSION OF LUBRICANTS

There are several factors that greatly affect the efficiency of transmitting pressure oil through the lubrication system. These are discussed in the following paragraphs.

Foaming

Foaming is a basic problem in all lubricating systems. It is created by spraying oil from jets to the bearings and couplings and also by

Table 8-1.—Classification of lubricating oils.

NATO number	MIL spec & grade	Use
0-133	MIL-0-6081 Gr. 1010	Early turbine engine lube oil. fuel system preservative and oil.
0-123	MIL-L-22851 Type III	Ashless dispersant piston engine oil. (Used principally by the Army for small aircraft engines.)
0-128	MIL-L-22851 Type II	Ashless dispersant piston engine oil.
0-148	MIL-L-7808	Three centistoke turbine engine synthetic lubricating oil.
0-156	MIL-L-23699	Five centistoke turbine engine and gearbox oil.

the churning effect induced by the accessory drive gears and scavenge elements of the lubricating pump.

Heat Expansion

In dry sump lubrication systems, the oil tank is provided with expansion space, which allows for foaming and heat expansion of the oil. In addition, oil tanks are sometimes pressurized slightly or vented to atmosphere to partly retard foaming and at the same time to apply a head pressure on the oil at the lubricating pump inlet to assure a more positive flow. Also, de-aerator trays are sometimes used to separate air from the oil, wherein the air escapes to the outside via the vent line.

In the wet sump oil system, foaming and heat expansion space is provided in the crankcase since the oil level only partly fills the casing. De-aerator trays are also used in most crankcases to make easy air removal from the oil, whereby air escapes through the oil breather.

Temperature Extremes

The effect of temperature extremes on engine lubricating oil also affects the flow of pressure oil. A reciprocating engine may be started where the air temperature is 100° F or more, and within a short period of time the aircraft may be at 25,000 feet altitude where the air temperature is approximately -30° F. Naturally, this temperature extreme will greatly affect the viscosity of the oil and slow down its flow. However, since the lubricating oil is antifreezing, it will not congeal, although the oil pressure readings will be higher than they would ordinarily be at sea level.

Efficiency of the Oil Venting System

Another factor which affects the flow of oil through the lubrication system is the efficiency of the oil venting system. If the pressure in the bearing compartments is not controlled, the oil does not flow properly from the main bearing oil jets. Some engines use vents alone; others, a breather pressurizing system to assure proper oil flow to the bearings.

DRY SUMP SYSTEM

The dry sump system is the most widely used system in aircraft engines. In this system the main oil supply is carried in a separate tank. Oil draining from the various engine parts is collected in one or more sumps and is returned by means of a scavenge pump to the oil tank. Some of the larger engines used in the Navy have two or more sumps attached to various sections of the engine, with separate scavenge pumps located in each sump.

All radial aircraft engines have the dry sump lubricating system. It is obvious that no great amount of oil could be carried in the crankcase of an engine of this type without flooding the lower cylinders. Also, the great amount of heat that is absorbed by the oil in its movement ghroughout the system makes the use of an external cooling system necessary.

The complete system required for the lubrication of a dry sump engine is subdivided into two separate, though interconnected, systems; the engine internal lubrication system and the external lubrication system.

The engine internal lubrication system consists of all the pressure and scavenge pumps, strainers, pressure control devices, oil passages, and all other components the engine manufacturer incorporates into his product.

The external lubrication system includes all the oil system components which the designer of the airframe incorporates into the aircraft. These include all storage, temperature control, and external oil system components, together with the necessary oil lines and connections to the engine lubrication system, as well as oil temperature and oil pressure indicating systems. An oil dilution system is incorporated in some aircraft. It is discussed in later paragraphs.

EXTERNAL OIL SYSTEM

Although the arrangement of the oil systems in different aircraft varies widely, as do the construction details of the various components, the functions and operations of all parts of these systems are similar. The study of one system by the Aviation Machinist's Mate R will make clear the general operation and maintenance requirements of all systems.

In any installation, the equipment is compactly arranged between the engine and the fire-wall and placed as closely to the engine as practicable. Most of the components are fitted into or attached to the engine or the engine mount structure.

In multiengine aircraft, each engine has its own independent oil system, with some installations providing a reserve tank from which oil can be transferred to the individual engine. The components of the SP-2H external lubrication system, their relationship with each other, and the path of flow of the oil in the system are illustrated in figure 8-1.

Each engine is provided with a complete external oil system, which includes the following units:

1. A self-sealing tank and hopper assembly.
2. An oil foam tank, oil coolers, and temperature regulator valves.
3. Oil cooler doors and thermostatic control system.
4. Manual shutoff valves.
5. A temperature-controlled diverter valve.
6. A capacitance oil quantity system.
7. An oil dilution system.
8. All the necessary plumbing.

In the operation of this particular oil system, the temperature is maintained automatically or by manual operation. Not all oil systems in use in present-day naval aircraft are automatic in operation and thus a closer watch of the oil temperature must be maintained at all times.

Engine oil is supplied through a standpipe in the tank sump; propeller feathering oil is supplied from a point below the engine oil standpipe level (multiengine aircraft only). Oil flowing through the system makes a complete cycle from the tank to the engine and back to the tank.

Oil flows by gravity feed from the tank to the engine rear oil pump. A direct line from

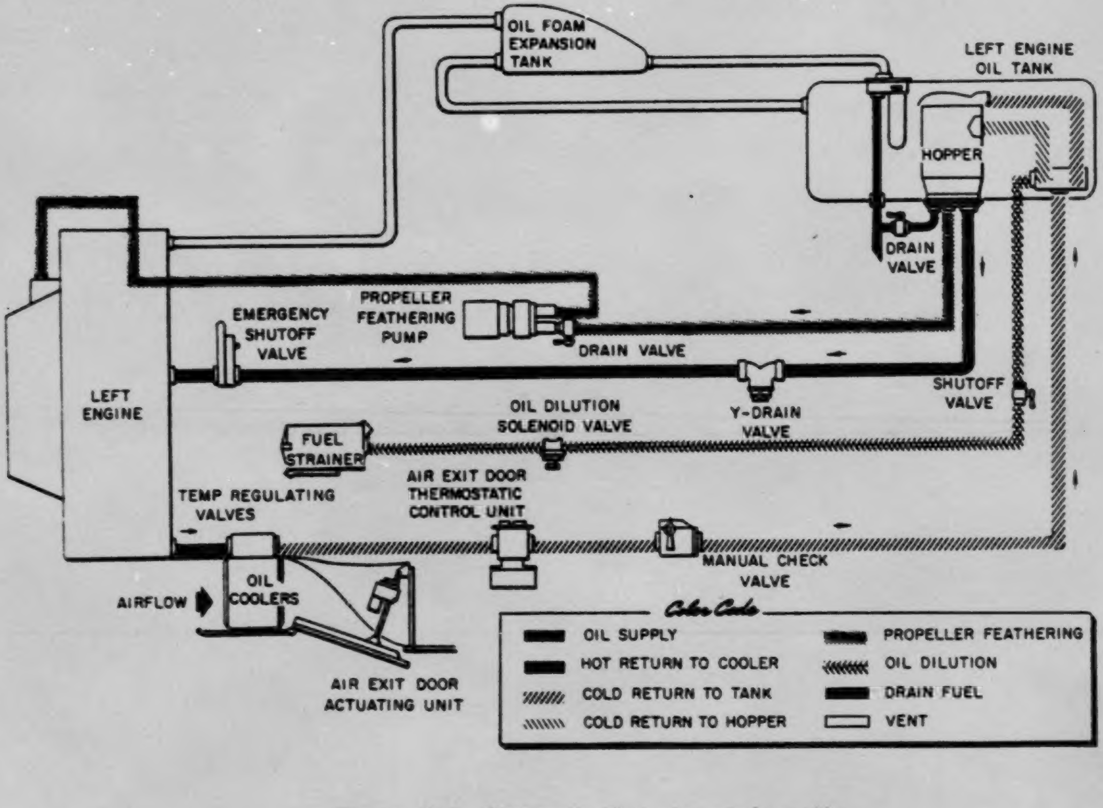
OIL FOAM EXPANSION TANK
LEFT ENGINE OIL TANK
HOPPER
DIVERTER VALVE
DRAIN VALVE
PROPELLER FEATHERING PUMP
EMERGENCY SHUTOFF VALVE
DRAIN VALVE
LEFT ENGINE
SHUTOFF VALVE
OIL DILUTION SOLENOID VALVE
Y-DRAIN VALVE
FUEL STRAINER
AIR EXIT DOOR THERMOSTATIC CONTROL UNIT
TEMP REGULATING VALVES
MANUAL CHECK VALVE
AIRFLOW
OIL COOLERS
AIR EXIT DOOR ACTUATING UNIT
Color Code
OIL SUPPLY
HOT RETURN TO COOLER
COLD RETURN TO TANK
COLD RETURN TO HOPPER
PROPELLER FEATHERING
OIL DILUTION
DRAIN FUEL
VENT

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Figure 8-1.–External oil system schematic.

the tank carries the oil to the engine. Oil returning from the engine is routed through an oil temperature regulator valve. The regulator valve(s) are attached to the oil cooler(s), which dissipate excess heat from the oil.

Oil flows from the regulator valve through a thermostatic control unit, where the temperature of the oil affects the positioning of the oil cooler doors controlling the amount of air flow passing through the oil cooler.

Before the oil completes its cycle, it flows through the temperature sensitive elements of the diverter valve. This valve determines whether the oil from the engine is returned to the main part of the tank or to the hopper within the tank. During oil dilution, gasoline is introduced into the oil system through the temperature sensitive elements of the diverter valve; the valve allows the mixture to be returned only to the hopper, where it is stored until the engine is started again.

An emergency shutoff valve is installed in the oil supply line at the firewall. This shutoff valve is operated by the emergency shutoff lever mounted in the overhead at the flight station overhead control panel.

Tank

The oil tank in this particular system may or may not be a self-sealing type oil tank. It may also be a bladder type tank, depending on the bureau number of the aircraft. This is also true of other type of aircraft; therefore, always check the Maintenance Instructions Manual for the specific information needed.

The tank is serviced through a capped filler well which is accessible from the top of the wing. The filler well has a scupper drain line attached to it to drain excess oil over the side. Each tank has a capacitance type quantity transmitter. Each tank in this system has a total capacity of 87 U.S. gallons. The tank can be filled with 80 gallons of usable oil plus 2.5 gallons which are retained in a well in the bottom of each tank for feathering the propeller. This system also incorporates a 20-gallon foam expansion tank separate from the main oil tank.

During cold starting operations, oil is returned only to the hopper where it is quickly returned to the engine. In this manner, a small volume of oil may be quickly warmed to the proper operating temperature. As the temperature rises, the remaining oil in the tank is warmed until it reaches the proper operating temperature. How this is accomplished will be explained later in the section pertaining to the oil diverter valve.

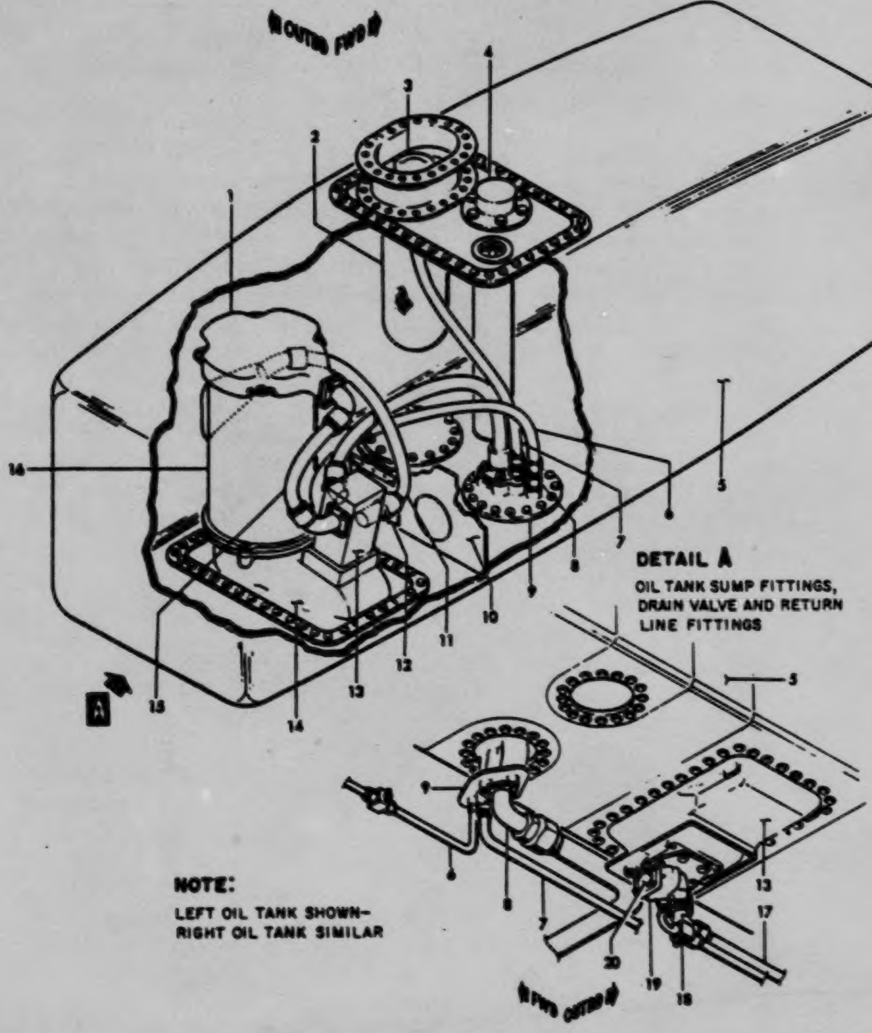
The oil tank can be cleaned with an approved drycleaning solvent. Do not use carbon tetrachloride or any caustic cleaner. If a new engine is installed because of an engine failure, clean and inspect the inside of the tank and its component parts. Make certain there are no metallic particles or foreign matter present in the tank which could be recirculated, possibly causing another engine failure. The tank should be drained at the "Y" drain valve and at the tank sump drain valve. The tank cover plate should then be removed and the inside of the tank thoroughly cleaned. See figure 8-2 for description of the oil tank.

Expansion Tank

The oil foam expansion tank is not found in most external oil systems, as the foaming space for the oil is incorporated in the oil tank itself. The SP-2H oil foam expansion tank is an aluminum type tank attached to the top surface of the upper stress panel and shaped to fit beneath the engine nacelle fairings. Two plumbing lines connect the foam tanks with the oil tanks, allowing foaming oil to expand into the foam tank. A third line vents the tank to the engine. The foam tank has a capacity of 20 gallons and is protected by an insulated covering.

Oil Cooler and Temperature Control

The oil cooler is designed to dissipate heat picked up by the oil in its flow through the engine, and to dissipate that heat to the atmosphere. The amount of heat dissipated, or the regulation of the oil-out temperature, is controlled by various valves of various types. They exercise temperature control by routing the oil through one of two paths through the oil cooler or bypasses the oil cooler altogether when the oil temperature is low enough. Additional temperature regulation is provided by the oil cooler exit doors, which regulate the air flow through the cooler core. These doors or shutters may be thermostatically controlled as shown in the


OUTBD FWD
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FWD OUTBD

DETAIL A
OIL TANK SUMP FITTINGS, DRAIN VALVE AND RETURN LINE FITTINGS

NOTE:
LEFT OIL TANK SHOWN-
RIGHT OIL TANK SIMILAR

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1. Diffuser cap.
2. Strainer.
3. Fillercap.
4. Quantity transmitter.
5. Oil cell.
6. Dilution line.
7. Scupper drain line.
8. Oil to diverter valve.
9. Oil return line.
10. Baffle.
11. Oil return to hopper.
12. Flapper valve.
13. Diverter valve.
14. Sump assembly.
15. Oil return to tank.
16. Hopper assembly.
17. Propeller feathering line.
18. Sump drain valve.
19. Sump fitting.
20. Oil to engine.

Figure 8-2.—Oil tank assembly.

schematic diagram of the external oil system in figure 8-1, or may be manually positioned by an electrically operated screwjack.

The SP-2H has two oil coolers mounted side by side for each engine installation. They are mounted directly under the accessory section of the engine. Each includes a 17-inch aluminum cooler upon which is mounted an oil temperature regulator valve. The two oil coolers are connected in parallel in the oil return line. (See fig. 8-3.)

Each oil cooler consists of a central core, which is completely enclosed by a warming jacket or muff. The core is built up of thin wall aluminum tubes laid side by side horizontally. The tubes are divided into layers by horizontal baffles. The baffles are open at alternate ends, causing the oil flow to reverse at each baffle. A drainplug is provided at the bottom of the warming jacket. (See fig. 8-4.)

TEMPERATURE REGULATOR VALVE.–A temperature regulator valve is mounted on each cooler. The valve automatically directs oil flow through the cooler passages and also relieves surges and excess pressures which might cause damage to the cooler by bypassing the oil whenever a pressure buildup occurs during a cold start or other adverse pressure conditions.

In operation, the temperature regulator valve works in the following manner under normal conditions:

The thermostatic surge valve bypasses the return oil through the temperature regulator valve until the oil temperature rises to approximately 39.5° C so that excessive pressure is not imposed upon the cooler. As the oil temperature rises above 39.5° C, the thermostatic surge element gradually opens the oil cooler inlet valve while closing the disc valve. With the oil cooler inlet valve open and the disc valve closed, the oil flows through the cooler inlet valve port (port A) into the cooler, through the cooler bypass and back into the temperature regulator valve through port B, through the thermostatic valve port into the chamber containing that valve.

The oil then flows through the check valve port into the outlet chamber and through the "oil out" port. During this time the hot oil flows over the cooler, warming the oil within the cooler tubes. When the oil temperature reaches 54.4° C, the thermostatic valve closes so that the oil cannot return through port B, but must flow through the cooler, returning through port C across the thermostatic valve element, past the check valve, and to the "oil out" port. (See fig. 8-3.)

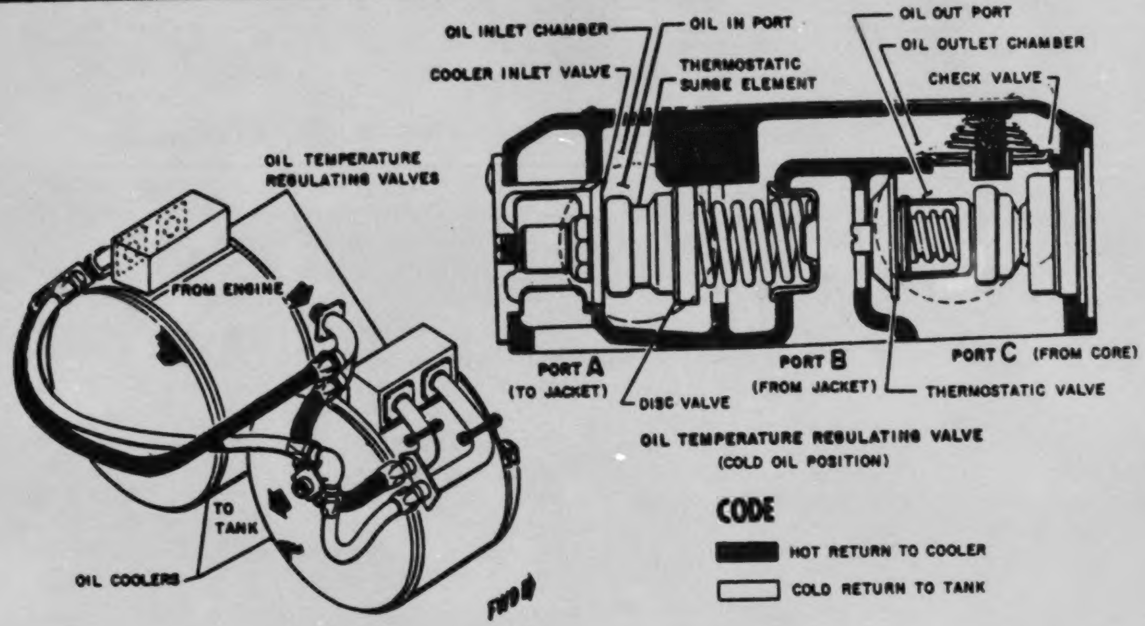
Apart from its thermostatic function, the surge valve overrides the natural resistance of the surge spring when the pressure differential between the OIL IN and the OIL OUT port exceeds 55 psi. As the pressure drops below 55 psi, this spring forces the thermostatic surge valve back into position. This purely mechanical action of the surge valve in no way affects its thermostatic action.

The thermostatic valve directs the flow of oil according to the oil temperature, varying flow through the cooler core to maintain proper temperature. This valve also operates as a spring-loaded relief valve when pressure develops after it is closed. It will relieve when the pressure differential acting on the valve exceeds 40 psi. The poppet check valve prevents oil from backing into the cooler core when the oil is under pressure.

AIR SYSTEM.–The cooling capacity of each of the oil cooler assemblies depends upon the amount of air that is allowed to pass through the cooler. Airflow through the cooler is governed by a controllable oil cooler door, which is located so that it restricts the opening of the oil cooler exit duct. The door is actuated by an electrically operated screwjack. A four-position switch on the copilot's console controls the electrical circuits to the actuator. The four switch positions are OFF, OPEN, CLOSE, and AUTOMATIC.

(NOTE: Some aircraft oil cooler door installations are not automatic and the position of the doors is maintained by the pilot, copilot, plane captain, or flight engineer.) With the switch in AUTOMATIC, the position of the oil cooler door (and therefore the oil temperature) is automatically regulated by a thermostatic unit through which the oil passes.

DOOR CONTROL CIRCUIT.–This circuit includes a motor-driven actuator mounted below the accessory compartment floor in each nacelle, automatically controlled by a thermostatic switch in the engine oil outlet line through a four-position switch on the copilot's switch console. The motor is a split field wound, reversible, 24-volt d.c., and includes a magnetic


OIL INLET CHAMBER
OIL IN PORT
COOLER INLET VALVE
THERMOSTATIC SURGE ELEMENT
OIL OUT PORT
OIL OUTLET CHAMBER
CHECK VALVE
OIL TEMPERATURE REGULATING VALVES
FROM ENGINE
PORT A (TO JACKET)
DISC VALVE
PORT B (FROM JACKET)
PORT C (FROM CORE)
THERMOSTATIC VALVE
OIL TEMPERATURE REGULATING VALVE (COLD OIL POSITION)
CODE
HOT RETURN TO COOLER
COLD RETURN TO TANK
TO TANK
OIL COOLERS
FWD

NOTE:
THERMOSTATIC VALVE OPENS WHEN PRESSURE AT PORT "B" EXCEEDS PRESSURE AT PORT "C" BY MORE THAN 40 P S I

VALVE OPERATION

CONDITION	OPERATION	PORTS A	PORTS B	PORTS C
ENGINE START COLD OIL	OIL FLOW THROUGH VALVE BYPASSING COOLER	CLOSED	BYPASSED	BYPASSED ★
OIL TEMPERATURE FROM 39.5 C. TO 43.3° C (103°F TO 110° F)	OIL FLOW THROUGH WARMING JACKET	OPEN	OPEN	BYPASSED ★★
OIL TEMPERATURE FROM 43.3° TO 54.4°C (110°F TO 130°F)	THERMOSTATIC VALVE CLOSES-OPEN ABOVE 54.4°C (130° F) ALL OIL FLOWS THROUGH COOLING CORE	OPEN	CLOSED	OPEN ★★
SURGE--COOLER INLET PRESSURE EXCEEDS OUTLET PRESSURE BY MORE THAN 55 P S I (COOLER INLET VALVE OPEN)	DISC VALVE MOVES ENTIRELY THROUGH ITS SEAT--OIL FLOWS THROUGH VALVE, BYPASSING COOLER	BYPASSED	BYPASSED	BYPASSED ★
		* CHECK VALVE CLOSED ** CHECK VALVE OPEN		

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Figure 8-3.—Oil coolers and temperature regulating valve.

brake to stop the motor quickly when the limits of travel, as determined by integral limit switches, are reached.

Power is supplied from the 24-volt d.c. forward power bus through the same 10-ampere circuit breakers which serve the cowl flap circuit. Each actuator is controlled automatically by a floating control thermostat installed in the engine oil return line on the right side of each main wheel well, just aft of the firewall. Two switches are located on the copilot's console for control of the oil cooler door cir-

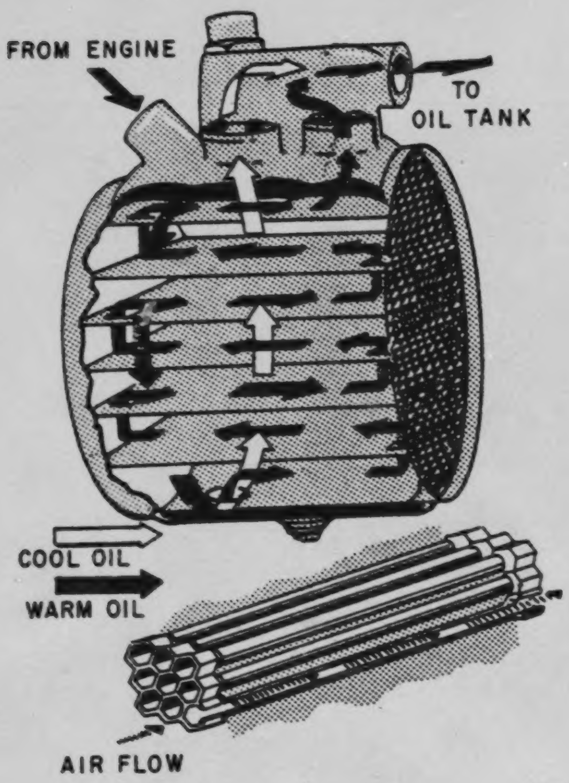

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Figure 8-4.—Oil cooler assembly construction.

cuits. The switches are of the four-position type, with OPEN, CLOSE, OFF, and AUTOMATIC positions. In the OPEN and CLOSE positions, the thermostat is excluded from the circuit and the actuator is energized directly: in AUTOMATIC, the actuator is controlled by the thermostat only.

AIR DUCTS.–Air entering the scoop in the lower cowl panel is fed through the lower cowl duct directly into the oil coolers. After passing through the coolers, the air passes through the exit duct (an integral part of the engine mount structure) and overboard through the thermostatically controlled oil cooler door.

DOOR AND DOOR ACTUATING UNIT.–The oil cooler door, fabricated from sheet metal, is piano hinged to the lower edge of the exit duct, just aft of the oil coolers. A bracket attached to the door provides an attachment point for the door actuator.

DOOR THERMOSTATIC CONTROL UNIT.–The door thermostatic control unit is mounted in the oil return line on the right side of the nacelle just aft of the firewall. The unit contains two floating contact arms and a central contact arm that is actuated by a bimetallic coil immersed in the oil in the return line. One of the floating contacts is in the DOOR OPEN circuit; the other is in the DOOR CLOSED circuit. The two arms rest on a cam, which is constantly rotated by a small motor. Thus the floating contacts are constantly vibrating toward the central contact.

If the oil temperature rises above normal, the thermostatic element causes the central contact to move toward the DOOR OPEN contact so that as the contact vibrates, it intermittently closes the DOOR OPEN circuit. As the actuator is intermittently energized, the door is slowly opened until the oil temperature returns to normal, at which time the central contact moves back to a neutral position. In an extreme case, where the oil temperature rises high above the normal value, the central contact will lift the floating contact clear of the cam, completing a continuous circuit. The door will then move toward the full open position, where a limit switch in the actuator will break the circuit.

If the oil temperature falls below normal, the central contact is moved in the opposite direction (toward the DOOR CLOSED contact), causing the door to close. In extreme cases, the central contact may lift the DOOR CLOSED contact from the cam, completing a continuous circuit to the motor and causing the door to move to its fully closed position, where a limit switch on the actuator breaks the circuit. To prevent excessive hunting, a tolerance of plus or minus 2.7° C is maintained by adjusting the cam follower of the floating contact.

MAINTENANCE.–The oil cooler assembly requires only cleaning when necessary. Failures of the regulator are usually caused by dirt or other obstructions under the valve seats. If the valve fails to function thermally, the remedy is to replace the defective element with a new one.

The thermal elements in the oil temperature regulator valve must be cleaned by immersion in solvent only and by blowing out immediately with an airstream. The valve body should be immersed in a suitable cleaning solution and

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cleaned thoroughly, using a brush. Blow out with compressed air.

Clean the oil cooler and temperature regulator valve as soon as possible after removal from the aircraft. Otherwise, the petroleum varnish, tar, and carbon compounds in the oil form a hard coating, difficult to remove.

Remove the drain plug, drain plug gasket, temperature regulator valve, and valve gasket from the oil cooler. Drain all residual oil from the cooler.

Immerse the cooler in a bath of oil cooler cleaning compound, MIL-C-6864A. Allow the cooler to stand in the bath for 5 minutes with tubes vertical. Move the cooler up and down occasionally to force liquid through the tubes and loosen grit; drain 10 to 15 minutes.

Use only recommended solvents. Many solvents satisfactory for cleaning copper oil coolers are highly corrosive to aluminum and will result in the destruction of the aluminum cooler if used.

Remove the cooler from the bath and drain with tubes in a vertical position. Using an air gun, blow out the tubes through the face of the core to remove foreign particles.

Attach the cooler to power flushing equipment, using only recommended solvents. The cooler should be connected to a power flushing system in such a manner that the solvent will enter the cooler through the outlet port.

If the flushing equipment has previously been used with any cleaning materials or solvent other than that recommneded, the equipment should be washed out thoroughly and flushed with MIL-C-6864A. The power system should be equipped with a suitable filter to prevent recirculation of foreign matter. A relief valve set to relieve at 75 psi must be provided to prevent damage to the cooler from excessive pressure.

With the bypass port closed and the inlet port open, pump solvent into the outlet port of the cooler. Flush for 60 minutes, reversing the flow each 10 minutes. This cleans the inside of the core and warmup passage.

Open the bypass port, close the inlet port, and continue flushing for 5 minutes. This removes dirt which may be trapped in the bypass passage.

Rinse the unit thoroughly with solvent PS-661b.

With clean approved solvent, flush 30 minutes, reversing flow once.

Drain the cooler thoroughly and flush with clean light lubricating oil at a temperature of 54.4° C.

NOTE: After each flushing operation the filter screen should be examined. If metallic particles are found, it is an indication that the oil cooler was installed on an engine that failed. Since there is no known method of determining whether all metallic particles have been removed from the core, every oil cooler assembly removed because of engine failure shall be tagged, giving the cause, and turned into supply.

The maintenance of the oil cooler door actuating unit consists of wiping the unit with a clean rag dipped in approved solvent. If the motor brushes are worn excessively, they should be replaced. The actuator support bearings should be lubricated at the intermediate inspection with MIL-L-7870. The drivescrew should be packed with grease as specified in the Periodic Scheduled Maintenance Requirements Manual. See table 8-2 for oil cooler door actuating unit troubleshooting.

If the oil temperature gage constantly registers below 77° C or above 82° C, check the gage for accuracy; if inaccurate, replace the gage. If correct, adjust the floating control thermostat of the door thermostatic control unit.

The oil cooler door thermostatic control unit troubleshooting information is in table 8-3.

Oil Temperature and Pressure Gages

The actuating unit of the oil temperature gage is located in the engine oil inlet, and is connected to a temperature gage in the cockpit instrument panel.

The oil temperature gage consists of either a thermocouple unit and a suitable meter, or a resistance unit coupled through a Wheatstone bridge to a suitable meter. In either case, the gage heat unit is always a sensitive electric meter calibrated in degrees centigrade. Operation of the electric oil temperature gage which uses the resistance bulb unit is based upon the principle that the conductivity of an element of known resistance varies with the temperature.

The oil pressure gage is used to provide the pilot with a reading, in pounds per square inch,

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Table 8-2. —Oil cooler door actuating unit troubleshooting.

Trouble	Probable cause	Remedy
Failure to operate.	Burned-out motor.	Replace actuator.
	Faulty wiring.	Check circuit and tighten all connections.
	Inoperative limit switch.	Replace actuator.
	Jammed gear train or screwjack.	Replace actuator.
Door opens but will not close, or vice versa.	Burned-out field in motor.	Replace actuator.
	Burned-out limit switch.	Replace actuator.
Door does not completely open or close, or both.	Improper setting of limit switches.	Reset limit switches.

of the oil pressure being supplied to the engine. A gage in the cockpit instrument panel is connected to the engine at a point downstream of the engine oil pump. The pressure orifice (opening) is restricted in size to a No. 60 drill so that pressure surges and fluctuations of oil pressure will not be harmful to the gage.

Emergency Oil Shutoff Valve

A shutoff valve controlled by the E-level is provided in the oil supply line to each engine. By closing this valve, all oil flow to the engine may be cut off in the event of fire or other emergency. The valve is in the wheel well, just aft of the firewall, and is accessible from within the wheel well. The valve controls are located aft of the pilot's seat.

Manual Check Valve

A flapper type manual check valve is installed in the oil return line, aft of the firewall on the right side of each wheel well. This check valve prevents oil in the return lines from draining into the engine compartment in case the oil return lines are broken by fire or in other emergencies. If it is desired to drain the return lines, the check valve may be manually opened by moving the spring-loaded lever in a counterclockwise direction. Normally, the lever must be safetied in the down position.

Inspect the manual check valve for leakage. This is accomplished by disconnecting the oil return manifold at the firewall fitting and prying the manifold fittings ahead to check for leakage. If leakage exceeds 20 drops per minute, replace the valve. Replace the valve at every aircraft overhaul.

Oil Drain Valve

A Y-drain valve is located on the left side of each wheel well, aft of the firewall. The valve is a two-position, poppet type valve for draining the engine oil tank and system, except for approximately 2 1/2 gallons which remain in the tank for feathering the propeller. The valve should be safetied in the OFF position.

Table 8-3.—Oil cooler door thermostatic control unit troubleshooting.

Trouble	Probable cause	Remedy
Failure to operate in manual or automatic.	Low battery in aircraft power system.	Replace the battery.
	Defective thermostat assembly motor.	Replace the unit.
Unit operates in manual but not in automatic.	Thermostat motor burned out.	Replace the unit.
	Center contact arm loose.	Tighten the center contact arm.
	Loose connection at the contact points.	Tighten all connections.
Door closes but does not open, or vice versa.	Failure of thermostat motor to turn cam.	Replace the unit.
Excessive movement of the door.	Incorrect setting on the contact points.	Reset the points to the proper gap with the floating contact arm in the depression on the cam.
Oil present in the cover box.	Leakage past the seal on bimetal element shaft.	Replace the unit.
Failure of the thermostat motor to turn the cam.	Worn-out brushes.	Replace brushes.
	Jammed gear unit.	Replace the unit.
Excessive chattering of the contact points.	Burned-out resistors.	Replace the resistors and the contact points.
Failure to maintain the proper oil temperatures.	Loose or oscillating contact points.	Reset and tighten in place.
	Floating contact arms binding on pivots.	Oil the pivots lightly. (Use SAE 10 lubricating oil.)

Oil Dilution System

An oil dilution system is provided for each engine oil system to provide good engine lubrication during cold weather starting.

During dilution, a small amount of gasoline is mixed with the oil in both the engine and oil tank hopper assembly. Fuel for dilution is tapped from the main fuel strainer in the wheel well, and metered through a No. 47 hole restrictor.

When the system is energized, fuel is fed through a solenoid-controlled valve and a manual shutoff valve to the Vernatherm unit in the diverter. valve. Within the diverter valve the cold fuel causes the temperature sensitive unit to move the valve to the hopper position, so that diluted oil is only returned to the hopper. Control of the system is through momentary contact switches on the copilot's switch console. The electrical circuits are so interconnected that when the oil dilution solenoid is energized, the boost pump for the fuel tank selected is automatically operated in HIGH BOOST operation.

A solenoid-operated oil dilution valve is located on the left side of each wheel well and is accessible from within the wheel well. The valves are controlled by a momentary contact switch located on the left side of the copilot's switch console. Gasoline is furnished to each valve by a small line attached to the fuel strainer, which is just aft of the valve. The gasoline is delivered to the oil system by another small line leading from the valve to the diverter valve at the aft wheel well bulkhead. A small manual shutoff valve is installed in the line at the diverter valve. The shutoff valve must be lockwired closed at all times except during dilution.

The operational check of the oil dilution valve is performed as follows:

1. Close the manual shutoff valve in the dilution line beneath the tank.
2. At the dilution solenoid valve, disconnect the line leading to the diverter valve.
3. Set the mixture control at CUTOFF.
4. Set the ignition switch at OFF.
5. Place an empty container under the oil dilution valve.
6. Select a tank containing fuel.
7. Set crossfeed for normal flow.
8. Turn the oil dilution valve switch to ON.
9. Check to see that fuel has been delivered by the valve.
10. Check to see that booster pump in fuel tank selected has been actuated in HIGH BOOST.

Oil Quantity Indicating System

A Minneapolis-Honeywell oil quantity indicating system is installed. This system includes tank capacitor units, power calibration units, indicator units, and necessary cabling. All adjustment to the system is accomplished at the power units.

The three basic components (tank unit, power unit, and indicator) compose a continuously balancing capacitance bridge circuit. The tank unit, mounted in the oil tank, is a cylindrical electrostatic capacitor in which the capacitance varies with changes in oil level and dielectric constant. Any change in tank unit capacitance will unbalance the bridge and supply a signal to the amplifier section of the power unit. The power unit will then energize the phase-sensitive motor in the indicator. The indicator motor drives the balancing potentiometer wiper in the direction required to restore the bridge to balance at the new point of balance. The indicator pointer, which is driven by the same shaft as the potentiometer wiper, is positioned at the correct reading of oil quantity.

INTERNAL OIL SYSTEM

The pressure and scavenge oil systems and their components are covered in this section. The model R3350-32W engine is considered a typical engine, as this engine utilizes a pressure, dry sump type oil system.

The purpose of the internal oil system is to provide pressure oil for lubrication of moving parts, to aid in cooling of the internal parts through oil circulation, and to flush and clean internal parts of foreign matter. All moving parts are lubricated by oil under pressure except the piston rings, piston pins, cylinder walls, intake and exhaust valves, crankshaft main bearings, and propeller shaft thrust and radial bearings, all of which are lubricated by splash or jet. Another function of the internal oil system is to provide operational oil for the following units:

1. Torquemeter system.
2. Propeller and governor.
3. Oil-operated plate clutch.
4. Power recovery turbine fluid couplings.

The oil system also aids in preventing corrosion of internal parts of the engine.

Rear Sump

The rear sump is located on the bottom of the rear supercharger section. It collects, circulates, and returns the oil. It also acts as a housing for the components. Usually the port side is referred to as the pressure side; the starboard, as the scavenge side.

The rear sump housing is made of cast magnesium and contains the various units needed in the operation of the pressure and scavenge oil system.

Pressure System

Pressure oil leaving the rear sump supplies the front supercharger section, front sump, rear supercharger cover, tachometer generator, engine-driven fuel pump bearing, and the oil-operated plate clutch.

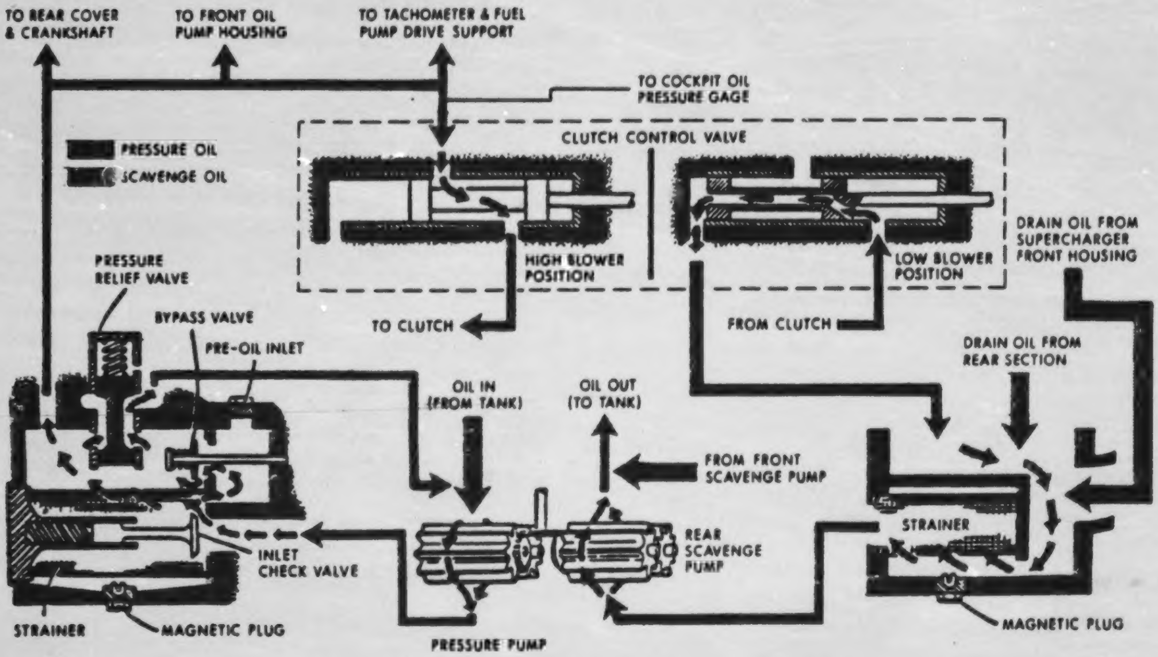
REAR OIL PRESSURE PUMP.–The rear oil pressure pump is the cartridge type with two spur steel gears in a machined aluminum housing (See fig. 8-5.) There are two openings on the top of the pump for the inlet oil and one opening on the bottom for the pressure oil leaving the pump.

PRESSURE STRAINER.–The pressure strainer consists of a series of corrugated steel disks separated by fine wire mesh screens and secured together to form a cylindrical strainer. Half of the disks are corrugated on the inner edge and the other half on the outer edge. They are placed alternately in series to provide straining action. The oil enters the center of the strainer and then flows from the center to the outside. This prevents collapsing of the strainer.

CHECK VALVE.–The check valve is made of stainless steel and is located on the pressure strainer. All oil going to the engine must pass through this check valve. There is a spring that keeps the valve closed when the engine is not running, to prevent flooding of the engine with oil from the tank.

BYPASS VALVE.–The bypass valve is operated on a differential of oil pressure and is located in the strainer cavity. It insures that lubricating oil will get into the engine in the event that the strainer is clogged or the oil is too heavy to flow through the strainer.

PRESSURE RELIEF VALVE.–The pressure relief valve regulates oil pressure to the engine. It is a double-ended bronze valve in a cadmium-plated steel housing. This valve incorporates a


TO REAR COVER & CRANKSHAFT
TO FRONT OIL PUMP HOUSING
TO TACHOMETER & FUEL PUMP DRIVE SUPPORT
TO COCKPIT OIL PRESSURE GAGE
CLUTCH CONTROL VALVE
PRESSURE OIL
SCAVENGE OIL
HIGH BLOWER POSITION
LOW BLOWER POSITION
DRAIN OIL FROM SUPERCHARGER FRONT HOUSING
PRESSURE RELIEF VALVE
BYPASS VALVE
PRE-OIL INLET
TO CLUTCH
FROM CLUTCH
DRAIN OIL FROM REAR SECTION
OIL IN (FROM TANK)
OIL OUT (TO TANK)
FROM FRONT SCAVENGE PUMP
REAR SCAVENGE PUMP
STRAINER
INLET CHECK VALVE
STRAINER
MAGNETIC PLUG
PRESSURE PUMP
MAGNETIC PLUG

AD.60

Figure 8-5.–Diagram of the rear oil pressure pump.

spring and an adjusting screw which provide a means of regulating the oil pressure. Oil pressure adjustment procedure is described later in this chapter.

SUPERCHARGER CLUTCH OIL CONTROL VALVE.–The supercharger clutch oil control valve is located on the rear center of the sump. It controls the oil to the oil-operated plate clutch. It is operated by a control in the cockpit.

Scavenge System

The purpose of the rear sump scavenge system is to strain and return the oil to the external oil system. (See fig. 8-5.) This is accomplished with units located in the front and rear sumps; however, all scavenge oil leaves the sump by an external line on the right side of the sump.

REAR OIL SCAVENGE PUMP.–The rear oil scavenge pump is the cartridge type. It has two sets of spur steel gears in a machined aluminum housing. This pump has two inlets at the bottom and one outlet at the top.

REAR SCAVENGE STRAINER.–The rear scavenge strainer is the mesh screen type. It strains all the scavenge oil from the rear power section and aft of the rear power section.

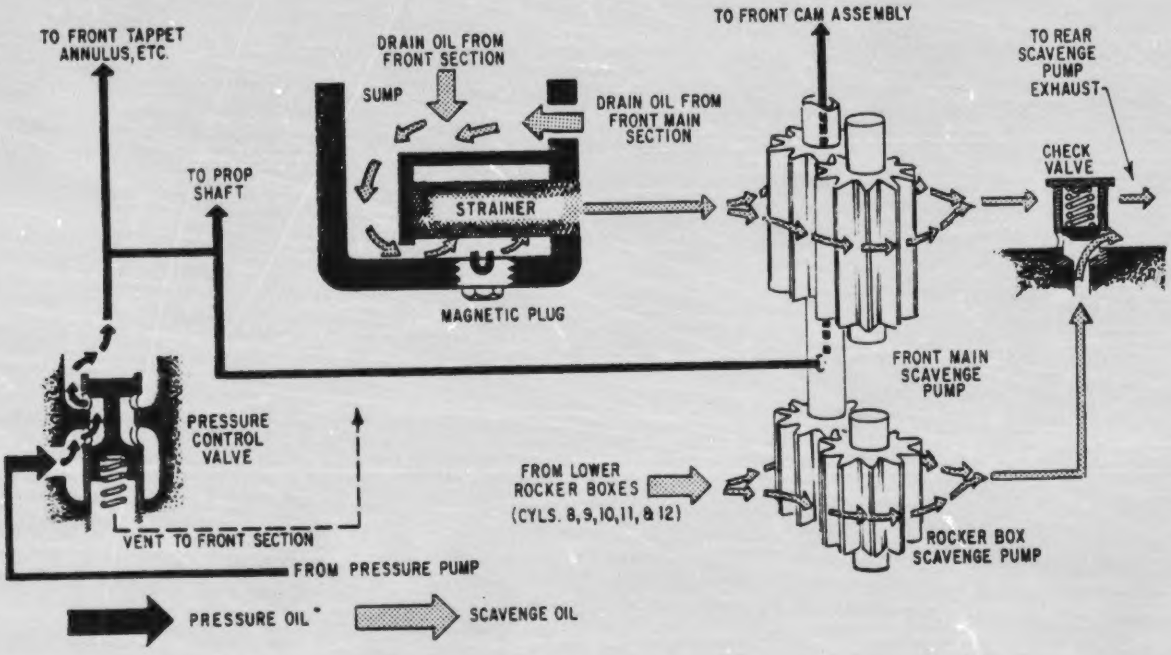
A magnetic plug is located just below the strainer to attract ferrous metal, thereby protecting the scavenge pump.

FRONT SUMP.–The front sump is located on the bottom of the front crankcase section. It collects, circulates, and returns the oil and acts as a housing for components. The front sump housing is made of cast magnesium.

The pressure section of the front sump contains an oil pressure control valve. It reduces the oil pressure from the rear pressure pump to the pressure required for the front sump (35, plus or minus 5, psi).

The oil pressure passages in the front sump supply oil to the front tappet annulus, torquemeter system, and the front cam assembly. (See fig. 8-6.)

FRONT SCAVENGE PUMP.–Scavenge oil in the forward portion of the power section and the crankcase front section flows by gravity to the large scavenge pump in the front pump and sump


TO FRONT TAPPET ANNULUS, ETC.
DRAIN OIL FROM FRONT SECTION
SUMP
TO FRONT CAM ASSEMBLY
TO REAR SCAVENGE PUMP EXHAUST
DRAIN OIL FROM FRONT MAIN SECTION
CHECK VALVE
TO PROP SHAFT
STRAINER
MAGNETIC PLUG
FRONT MAIN SCAVENGE PUMP
PRESSURE CONTROL VALVE
FROM LOWER ROCKER BOXES (CYLS. 8, 9, 10, 11, & 12)
VENT TO FRONT SECTION
ROCKER BOX SCAVENGE PUMP
FROM PRESSURE PUMP
PRESSURE OIL
SCAVENGE OIL

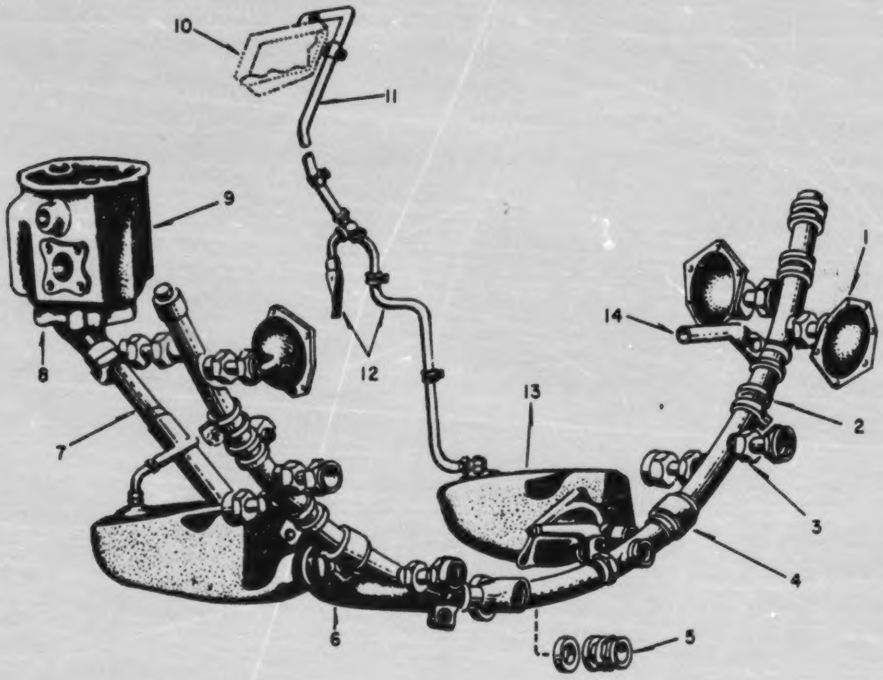
AD.61

Figure 8-6.–Diagram of the front oil pump.

housing. Before the oil enters the return pump it passes over a magnetic plug, through an oil strainer and then into the pump which is a spur gear type oil pump. The oil is then pumped back through an external line to the front supercharger housing and then internally to the rear sump outlet port.

ROCKER BOX SCAVENGE PUMP.– Drainage of the rocker boxes below the horizontal center-line of the engine is accomplished by a separate system. Scavenge oil flows by gravity from the rocker boxes through the rocker box cover through a connecting tube into the rocker box drain manifold.

Incorporated in the rocker box drain manifold system are two sumps configured into the rocker boxes of No. 10 cylinder. These sumps collect any oil that may drain down into the engine whenever it is setting idle, but whenever the engine is operating the oil is drawn from the sumps by the rocket box scavenge pump (first passing through a strainer) and is returned to the rear sump outlet port via the same external line as the oil from the front scavenge pump. (See fig. 8-7.)



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1. Rocker box cover.
2. Drain manifold.
3. Cover to drain manifold tube.
4. Rocker box drain manifold packing nut.
5. Drain manifold strainer.
6. Drain manifold to cover and sump tube.
7. Drain manifold to scavenge pump tube.
8. Rocker box scavenge pump.
9. Front oil pump.
10. Left distributor pad in front section.
11. Cover and sump vent upper tube.
12. Cover and sump vent lower left and right tubes.
13. Cylinder No. 10 rocker box cover and sump.
14. Rocker box scavenge manifold support bracket.

Figure 8-7.—Rocker box drain system.

MAGNETIC SUMP PLUGS.–The R-3350 engine incorporates in both the rear pump and oil sump and the front pump and sump MAGNETIC sump plugs. These plugs are removed whenever the engine is checked and the oil is drained at these points. The purpose of the magnetic sump plugs is to remove from the oil all types of metal in the engine oil that are magnetically attracted. Any indication of iron or steel on these magnets should be investigated. Some engines are now equipped with magnetic type sump plugs that are connected to warning lights in the cockpit that will indicate to the pilot a pending engine failure.

NOTE: The wet sump system is another type of lubricating system. The reservoir forms the lower part of the engine crankcase, as in the automobile. The oil is picked up by a pump and delivered to the points requiring lubrication. The oil then drains down into the crankcase and is pumped back through the system. The Navy does not use the wet sump system extensively for the following reasons: It has a limited amount of oil supply, provisions for cooling are difficult, oil temperatures are usually high, and it is not adaptable to unusual flight attitudes.

MAINTENANCE

Maintenance of the oil system is a major item of importance to the Aviation Machinist's Mate R. It is necessary for him to be thoroughly familiar with the oil system of the engine with which he is working, both the external and internal systems, so that he can effectively repair any leak or defect that may occur.

LOCATION OF LEAKS AND DEFECTS

The immediate location of any leak or defect within the external or internal oil system in any aircraft engine is of prime importance. The life of the engine is in its oil supply and whenever a leak develops or the oil flow is restricted because of a malfunction, a part failure or loss of the engine may result.

External Oil System

Locating common defects in the external oil system components is easily accomplished whenever the troubleshooter has a knowledge of the path of flow of the oil.

In operation, each engine oil system automatically maintains normal engine oil temperatures and a positive supply of oil to the engine without the attention of the pilot, copilot, or plane captain. The engine oil is supplied to the engine through a standpipe in the tank sump; propeller feathering oil is supplied from a point below the engine oil standpipe level. Oil flowing through the system makes a complete cycle from the tank to the engine and back to the tank. Oil flows by gravity feed through a flexible hose assembly from the main oil tank through the Y-drain valve to the engine rear oil pump.

Oil returning from the engine is routed through an oil temperature regulator valve. The oil temperature regulator valves are attached to the oil coolers and determine the path of flow through the oil coolers, around the air cooler jacket, or bypasses the oil coolers entirely. Any one of these actions is determined by the temperature of the oil.

Oil flows from the regulator valve through a thermostatic control unit, where the temperature of the oil affects the positioning of the oil cooler doors. This unit controls the volume of air flowing through the oil coolers by positioning the exit doors automatically.

Oil then flows through a manual check valve which prevents the return of oil from the external system when the engine is secured. Leakage from this valve, back into the engine, should not exceed 20 drops per minute.

The diverter valve is the final temperature control unit through which the oil passes before it returns to the tank. This valve determines whether the oil returning from the engine goes to the main portion of the oil tank or is returned to the hopper within the tank. Usually the only time this takes place is when the engine has been just started and the oil is still cold. The oil, in this case continues to return to the hopper until the surrounding oil in the tank warms up. Whenever oil dilution is used, gasoline is introduced to the oil system at the temperature sensitive elements of the diverter valve and is returned to the hopper portion of the oil tank. The gasoline is thus circulated from the hopper to the engine and back to the hopper, preventing the mixing of the diluted oil with the main oil supply.

An emergency shutoff valve is installed in the oil supply line at the firewall. This shutoff valve is operated by the E-lever (emergency) at the flight station overhead control.

Knowing the operation and the path of flow of the oil is of prime consideration whenever trouble-shooting is to be attempted. The path of flow and operation in the preceding paragraphs are those of the SP-2H aircraft engine, and we have used it here as a typical external and internal oil system. All recipocating aircraft engine oil systems have essentially the same characteristics as the one we have described here and it is therefore possible to use a standard set of troubleshooting procedures for the oil system.

One of the major causes of trouble in the engine oil system is contamination by metal particles. If metal particles are found in the oil system, usually an engine change is required. There is also the possibility that the oil system (tank, cooler, lines, and related engine accessories) is contaminated. Every precaution should be taken to keep contaminants from entering a newly installed engine. Through prompt identification of contaminants, the loss of time and materials required to flush the system may be avoided.

Metal particles found on the engine oil strainer and/or in the oil sumps usually are the first evidence of failure of a part within the engine. The presence of any metal particles on the oil strainer or in the oil sumps, however, is not necessarily an indication that the engine is no longer suitable for service. Metal particles from a previously installed engine which failed may have collected in sludge in the aircraft oil system. This possibility should be taken into account if metal particles are found in the sumps or on the strainers of the newly installed engine.

Carbon deposits in the engine frequently break loose in large pieces, which have the outward appearance of metal when found on the oil strainers and in the sumps. Carbon can be distinguished from metal by placing the foreign material on a flat metal object and striking it with a hammer. If the material is carbon, it disintegrates when struck, whereas metal of any type either remains intact or changes shape, depending upon its malleability. The particles of metal found in an engine may be any of five kinds: steel, tin, aluminum, silver, and copper or bronze. A visual inspection to determine the color and hardness occasionally is sufficient to determine the kind of metal present.

One of the most common external oil system defects is high or low oil temperature. Therefore, a chart as shown in table 8-4 will suffice to help identify this trouble.

Internal Oil System

Troubleshooting of the internal oil system is usually a matter of maintaining the proper oil temperature and pressures. Repair of leaks within the internal oil system is almost always restricted to the components of the engine that can be reached and repaired from the outside without dismantling the basic engine structure, (pushrods, rocker boxes, accessory mounting pads, etc.).

For the Aviation Machinist's Mate R to effectively locate internal oil system defects it is also necessary for him to be thoroughly familiar with the paths of flow of the oil as it progresses through the engine and returns to the external system. A brief description of the internal oil system flow path through the R-3350 engine is described in the following paragraphs.

NOTE: The information contained in these paragraphs is of a general nature and should not be used as specific information. Always refer to the applicable Maintenance Instructions Manual.

Oil from the external tank enters the pressure pump in the left side of the rear oil pump and sump housing. The pump discharges the oil through the cored passages in the pump and sump body into the inside of the pressure strainer, and then through the strainer into the strainer cavity. A strainer bypass valve allows the oil to bypass the strainer and provides the engine with oil for lubrication whenever the oil is too cold, or if the strainer should become clogged due to carbon or possibly a part breakdown. A spring-loaded check valve at the inlet side of the strainer prevents the flow of oil under gravity pressure from the tank whenever the engine is not operating.

The pressure relief valve in the rear pump and sump housing regulates the oil pressure to 70 psi, plus or minus 5 psi, during all engine operations. The quantity of oil flowing through the valve varies with the engine rpm, oil

Table 8-4. —Oil temperature troubleshooting chart.

Trouble	Cause	Remedy
High oil temperature.	Insufficient opening of oil cooler doors.	Open doors and watch temperature indicator for drop in temperature.
	Aircraft headed downwind.	Head aircraft into wind and note temperature.
	Improper setting of temperature control valve.	Replace temperature control valve.
	Oil cooler passages clogged.	Replace with new or serviceable cooler.
	Oil cooler air passages or ducts plugged with foreign matter.	Locate and remove obstructions.
	Internal oil passages partially blocked by sludge and foreign matter.	Replace cooler assembly.
	Improper regulator valve operation.	Replace valve.
	Low grade oil.	Check specification of oil used. If improper oil, drain system and refill with correct grade of oil.
Low oil temperature.	Oil cooler doors opened too far.	Close doors and check for temperature rise.
	Improper setting of oil temperature control valve.	Replace temperature control valve.
	Defective oil temperature indicator.	Replace with new or serviceable indicator.
	Defective temperature indicator bulb.	Replace with new or serviceable bulb.

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temperature, and the engine's demand for oil. An oil pressure control valve in the front pump and sump housing reduces the pressure of the oil passing through it to 35 psi, plus or minus 5 psi. Another oil pressure control valve in the supercharger front housing reduces the pressure of the oil passing through it to 50 psi, plus or minus 5 psi.

Tapped holes in the engine are provided for attaching pressure gages to check these various oil pressures. These holes are blanked off at all times except when it is necessary to check the pressure of the oil at a given point.

REPLACEMENT OF GASKETS, SEALS, AND PACKINGS

A large portion of the maintenance involved in the troubleshooting, replacement, and repair of various oil leaks and components of the oil system will involve the use of new gaskets, seals, and packings. The greatest difficulty encountered whenever a new gasket, seal, or packing is replaced is the proper installation. At all times, it must be ascertained that the mating surfaces are clean, old material removed, and the new gasket, seal, or packing is replaced in the correct manner. Always refer to the applicable Maintenance Instructions Manual for the correct procedure to follow.

ADJUSTMENT OF OIL PRESSURES

To identify defects in the oil system that are attributable to either high or low oil pressure, refer to table 8-5.

Always refer to the applicable Maintenance Instructions Manual for pressure limitations and the desired operating pressures for the engine with which you are working.

Front Sump Pressure (R-3350 Engine)

When it is necessary to adjust the oil pressure control valve in the front sump, remove the pressure gage substituting plug from the front sump. Connect an oil pressure gage at this location. Operate the engine at a speed of 2,600 rpm and an oil temperature of 85° C and observe the oil pressure. Adjust as follows if the pressure is not within the prescribed limits.

1. Secure the engine, and remove the pressure valve cap.
2. Push out the locking pin which passes through the holes in the body of the valve and the slots in the valve seat.
3. Turn the valve in a clockwise direction to increase the pressure and in a counterclockwise direction to decrease the pressure. Use a screwdriver with the proper blade width to avoid scarring the adjusting valve.
4. Set the front oil pressure to 35 psi, plus or minus 5 psi, install the locking pin. Install a new gasket and the control valve cap, tighten, and lockwire.
5. Shut down the engine and remove the oil pressure gage. Secure the plug in the oil pump and sump housing after the engine has been run up to the proper rpm and oil temperature and the pressure has been checked to ascertain that it is correct.

Supercharger Front Housing Oil Pressure (R-3350 Engine)

When it is necessary to adjust the oil pressure to the power recovery turbines, the plug located directly aft of the pressure control valve in the supercharger front housing must be removed. This is the point at which the oil pressure gage is installed so that the pressure may be read. The engine should be operated at a speed of 1,500 to 1,800 rpm with an oil inlet temperature of 85°C. If the oil pressure does not fall within the prescribed limits of 50 psi, plus or minus 5 psi, then the pressure must be adjusted in the following manner:

1. Remove the pressure control valve cap.
2. Push out the locking pin which passes through the valve body holes and the slots in the valve seat.
3. Turn the valve in a clockwise direction to increase the pressure and counterclockwise to decrease the pressure.

When the correct pressure is obtained, insert the valve body and seat locking pin. Install the control valve cap with a new gasket and lockwire. Shut down the engine and remove the oil

Table 8-5.—Oil pressure troubleshooting chart.

Trouble	Cause	Remedy
High oil pressure.	Low oil temperature.	Check temperature indicator. Check grade of oil.
	Improper setting of relief valve.	Reset pressure relief valve.
	Defective pressure indicator.	Replace with new or serviceable indicator.
Low oil pressure.	High oil temperature.	Check temperature indicator.
	Clogged oil strainer.	Remove and clean oil strainer.
	Improper setting of relief valve.	Reset pressure relief valve.
	Defective pressure pump.	Repair or replace pump.
	Defective pressure indicator.	Replace with new or serviceable indicator.
	Low oil level.	Fill oil tank to the proper level.
	Viscosity of oil is too light.	Drain system; refill with correct grade of oil.
	Air leak in the supply line.	Locate and eliminate air leak.
	Leaky oil dilution valve.	Remove fuel outlet line from valves. With fuel pressure applied and the valves off, no fluid should appear. If fluid appears, replace with new or serviceable valves.

pressure gage. Reinstall the plug in the supercharger front housing.

Rear Oil Pump Adjustment (R-3350 Engine)

The rear oil pump pressure of the engine is the pressure with which the mechanic is most often concerned. Whenever it is necessary to make an adjustment of the rear oil pump pressure the following procedures should be followed.

1. Operate the engine at a speed of 1,500 to 1,800 rpm with an oil inlet temperature of 85° C and observe the main oil pressure gage in the cockpit.
2. Remove the oil pressure relief valve cap and packing ring.
3. Loosen the adjusting screw locknut sufficiently so that the pressure adjusting screw may be turned clockwise or counterclockwise to increase or decrease the oil pressure. A one-quarter turn of the adjusting screw in either direction will raise or lower the pressure approximately 1 1/2 pounds per square inch.
4. When the correct pressure is obtained, tighten the locknut to the proper torque, install a new packing ring over the relief valve body and install, tighten and safety the cap.

CHAPTER 9

RECIPROCATING ENGINE IGNITION SYSTEMS

In the chapter concerning the cycle of operations in the engine cylinder, it was stated that the electrical spark used to ignite the air-fuel mixture charge was timed to occur at some point before top dead center of the compression stroke. The electrical system for producing, timing, and distributing this spark to the cylinders is called the IGNITION SYSTEM. As it is an electrical system, the ADR should have a thorough understanding of the properties of magnets, and the principles of electromagnetism and electromagnetic induction. This information is contained in the Rate Training Manual, Basic Electricity, NavPers 10086-B, supplementary reading for this manual.

All aircraft reciprocating engines used in the Navy are equipped with dual-ignition systems using magnetos. The use of a dual-ignition system serves two purposes: (1) It increases the safety factor, and (2) it increases engine output. If a defect in the ignition system occurs so that one of the two spark plugs in the cylinder, or one complete set of plugs, stops firing, the other plug or set of plugs will continue to provide ignition. The use of a dual-ignition system also increases engine performance over that possible with a single-ignition system by igniting the air-fuel mixture at two points in the combustion chamber, thus providing for a more rapid and more complete combustion. This is particularly important in modern high-speed, high-volume aircraft engines.

The ADR should note that in the normal operation of the engine, the ignition system functions independently of the other electrical systems of the aircraft; that is, with the engine running, the ignition system performs its function without electrical connection to the battery-generator system. In this respect the aircraft ignition system differs from that normally found in the automobile. The integral, independent character of the aircraft ignition system gives an added reliability desirable in flight operations. Failure of the battery-generator system in flight will in no way impair the functioning of the ignition system.

Two types of ignition systems are in general use on Navy aircraft. They are the LOW-TENSION SYSTEM and the HIGH-TENSION SYSTEM. They perform the same job, but have different characteristics.

Both types of ignition systems are shown schematically in figure 9-1 (A) and (B).

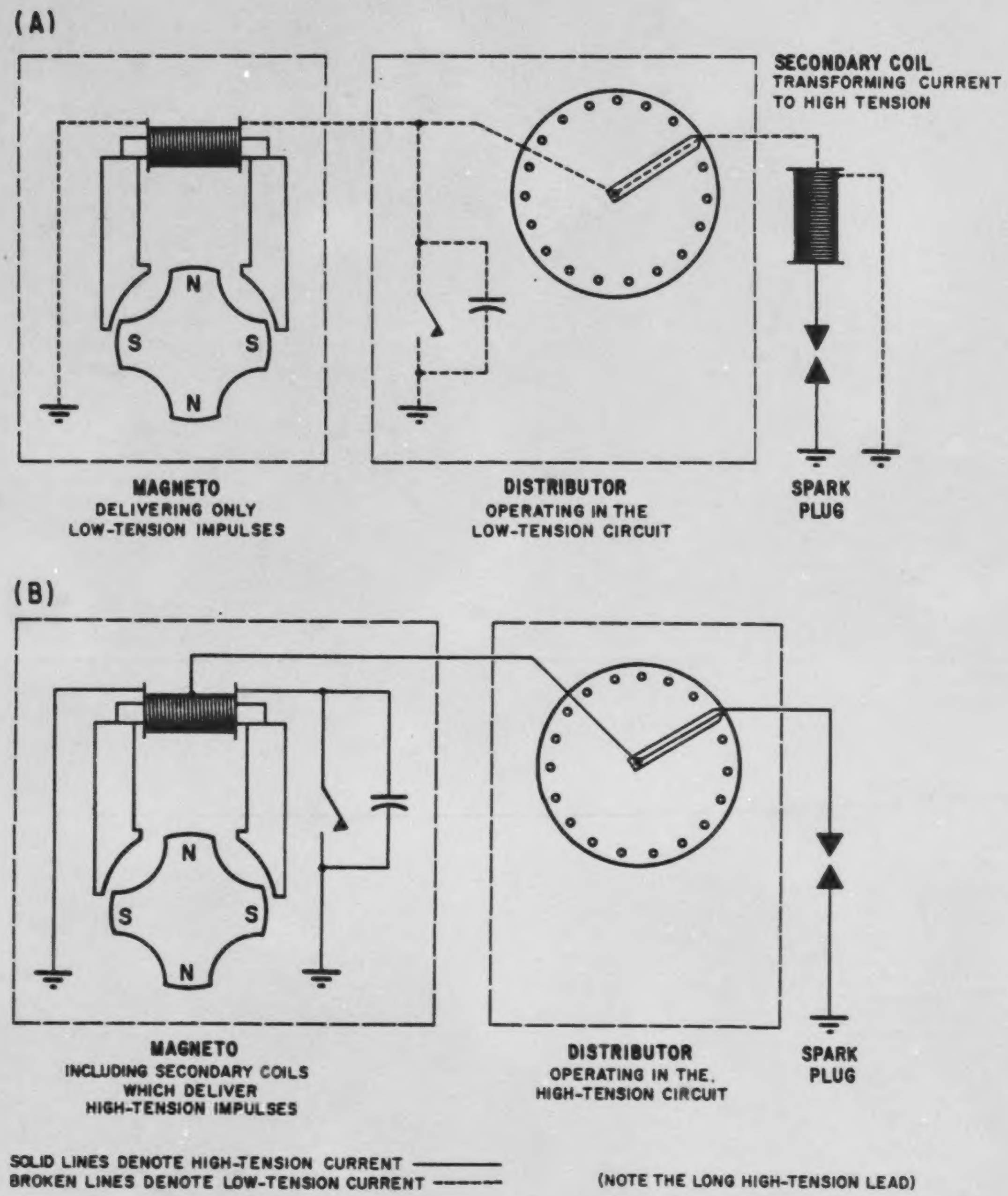
The various components of the engine ignition system are described in this chapter along with the general inspection, testing, handling, and storage, and the removal and installation procedures for each.

SPARK PLUGS

The maximum operating reliability of an aircraft engine depends to a large degree upon the efficient performance of the spark plugs. Therefore, the importance of proper servicing and installation techniques are essential to efficient spark plug performance.

In order to obtain the best operating performance, it is essential that all maintenance personnel be thoroughly familiar with the important aspects of aircraft spark plugs.

There are many seemingly unimportant factors which can influence the operation of spark plugs and which can mistakenly be taken to indicate that the spark plug is at fault, while actually, the trouble is caused by some other component part of the ignition system, or of the engine, or by improper maintenance or opera-


(A)
SECONDARY COIL
TRANSFORMING CURRENT
TO HIGH TENSION
N
S
S
N
MAGNETO
DELIVERING ONLY
LOW-TENSION IMPULSES
DISTRIBUTOR
OPERATING IN THE
LOW-TENSION CIRCUIT
SPARK
PLUG
(B)
N
S
S
N
MAGNETO
INCLUDING SECONDARY COILS
WHICH DELIVER
HIGH-TENSION IMPULSES
DISTRIBUTOR
OPERATING IN THE
HIGH-TENSION CIRCUIT
SPARK
PLUG
SOLID LINES DENOTE HIGH-TENSION CURRENT
BROKEN LINES DENOTE LOW-TENSION CURRENT
(NOTE THE LONG HIGH-TENSION LEAD)

AD.63

Figure 9-1.–Ignition systems. (A) Low-tension; (B) high-tension.

ting practices. In fact, the spark plug can often be used to give a general indication, by its appearance of faulty operation of other elements of the ignition system or of improper maintenance of the engine.

The tendency of frequently charging unsatisfactory engine operation to the spark plugs prevails primarily because of the temporary correction or remedy which is often realized by replacing spark plugs, which have become fouled or have been in operation for 30 hours or more, with new or overhauled spark plugs.

As the spark gaps widen from use, more stress is thrown on the other components of the ignition system; therefore, using spark plugs with large gaps, other parts of the ignition system can be causing the same trouble, but when plugs are changed, the new or overhauled spark plugs, having small gaps, apparently correct the trouble, but only temporarily.

Failures or poor performance characteristics commonly attributed to spark plugs, which new or overhauled spark plugs will sometimes correct, are as follows:

1. Weak insulation, moisture, or pinholes in the ignition leads.
2. Defective terminal contact sleeves.
3. Defective or poorly installed grommet where the shielding connects to the elbow.
4. Short insulation. Does not extend down flush with the contact spring ferrule.
5. Defective spark plug elbows.
6. Spark plugs and insulators improperly cleaned.
7. Improper operation of the engine.

There are two types of spark plugs in use at the present time; the platinum electrode (fine wire) type and the nickel alloy (massive) electrode type. The major spark plug elements are as follows:

1. The core insulator.
2. The shell.
3. The shielding barrel (is sometimes integral with the shell).

The core insulator consists of a body of nonconducting material such as ceramic, and contains the center electrode with a sealing device for preventing gas leakage around the center electrode. The upper end of the center electrode is in contact with the spring contact of the high-tension lead and the lower end forms one side of the spark gap. A resistor is also sealed within the core of some plug types to prevent or reduce the erosion of the electrode during operation.

The shell is the portion of the spark plug that has the hexagonal section where a wrench may be applied, and below this section are the threads with which the spark plug is secured to the cylinder. The ground electrodes are secured to the lower end of the shell. (See fig. 9-2.) The shell supports the core insulator, and a seal is also provided to prevent the leakage of pressure into the spark plug from the results of compression and combustion.

The shielding barrel provides protection to the communication system of the aircraft by presenting a grounded metallic shield to prevent the high-tension lead or the center electrode from emitting electronic disturbances. The barrel of the spark plug contains an insulating sleeve which insulates it from the center electrode side of the spark plug gap. The upper end of the barrel is threaded for uniting the high-tension lead with the spark plug.

INSPECTION AND TESTING

Inspection of the spark plug before installation in the engine is of prime importance. The plug should be inspected for cleanliness, proper type, integrity of the ceramic insulation, the seat for the high-tension lead spring wire contact, and to insure that the threads are in good condition.

The testing of spark plugs can be accomplished by subjecting the plug to high voltage equivalent to the voltage present in the ignition system of the engine. The plug is installed in an approved "bomb" tester in the pressure chamber where it is subjected to a pressure of approximately 200 psi, using carbon dioxide. While under pressure, a motor-driven magneto supplies the necessary voltage to check the firing capabilities of the plug. Each plug should be given this test before it is installed in the engine. If the plug fails to fire or fires intermittently while in the tester, the plug should be rejected.

REMOVAL AND INSTALLATION

Removal of the spark plugs from the engine is a procedure with which the ADR will become

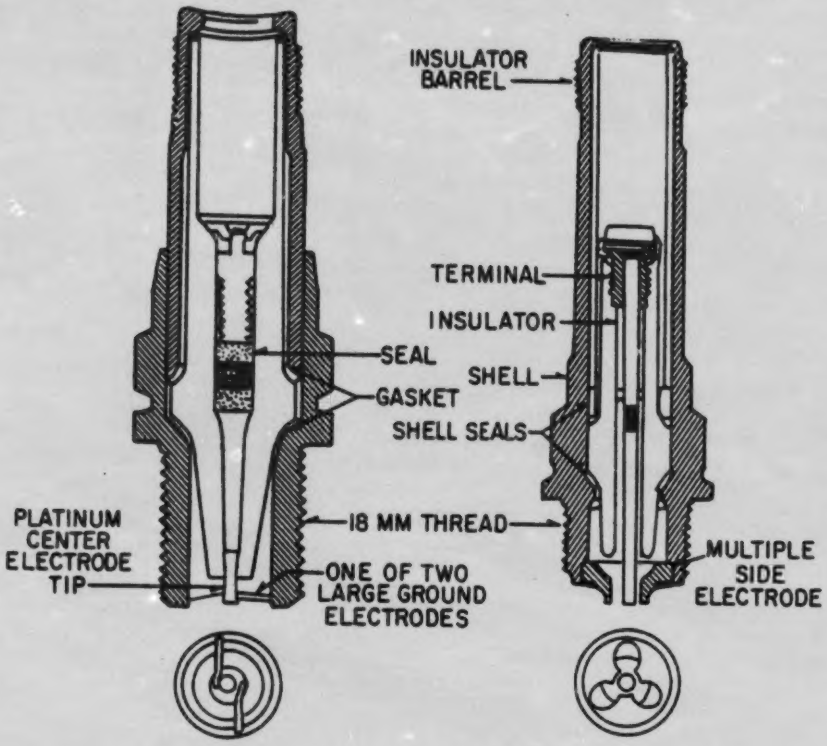


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Figure 9-2.—Spark plug construction.

well acquainted. Always use the proper tools for removal. Removal of the high tension lead from the spark plug is sometimes difficult. Care should be taken to remove the lead so that the elbow is not bent or twisted and that the high-tension lead ceramic sleeve is not cracked or broken.

Installation of the spark plug is the reverse of the removal procedure. Additional care should be taken during this procedure because if the plugs are installed improperly, malfunctions will occur and result in unnecessary labor and replacement of spark plugs. If a plug is dropped it should be tested or replaced with a good plug. The insulating ceramic within the plug may crack under any undue stresses or strains put upon it through dropping or unusual treatment.

NOTE: To insure correct torque value, the shell threads must be lubricated on plugs being reinstalled. It is not required when installing new plugs, for they are lubricated at the time of manufacture. The lubricant recommended in General Power Plant Bulletin (GPPB) No. 3, latest revision, is MIL-C-6529C, Type III.

Install a spark plug gasket, and run the plug into the cylinder spark plug bushing by hand. It should be possible to run the spark plug all the way into the bushing until it bottoms; if not, it may be necessary to clean the threads within the bushing. Once the spark plug has bottomed, complete the installation by tightening with a torque wrench to the required amount of torque applicable to the engine in which the spark plug is being installed. Install the high-tension lead and tighten the terminal sleeve nut, again being careful not to bend or twist the elbow.

HANDLING AND STORAGE

Aircraft spark plugs are of sufficiently sturdy construction to withstand the demands for which they are designed, but they are susceptible to damage from careless handling. The plugs should be handled individually and should never be thrown together as so much scrap material. They should be contained within their cartons or, after having been removed from the cartons, should be placed in trays suitable for handling. If spark plugs have been dropped or inadvertently banged around, they should be replaced with serviceable plugs.

Moisture is the worst enemy of spark plugs. After removing the spark plugs from the sealed container in which they are issued, they should be stored in a closed cabinet in which there is some type of heating element to keep the air warm within the cabinet. This is called a "hot locker," and its function is to lower the moisture content of the air in the cabinet. If plugs have been removed from the hot locker to be installed in an engine and cannot be installed within a reasonable amount of time, the plugs should be returned to the hot locker until they can be installed in the engine.

HIGH-TENSION IGNITION SYSTEM

The high-tension ignition system is still in use in some Navy aircraft engines. The ADR must be familiar with this system. It performs the same job as the low-tension system; that is, it furnishes dual ignition to the proper cylinder at the proper time.

The high-tension system consists of either two separate magnetos or one duel magneto and two distributors. In those systems that use two separate magnetos, the distributors are located in the magnetos. When a dual magneto is used, two separate distributors are used.

In the high-tension system, high-voltage current is developed in the magneto, as can be seen by referring to figure 9-1 (B). The system also includes a harness, two spark plugs for each cylinder, an ignition switch, and a starting vibrator.

The ADR should have a clear understanding of the types and uses of aircraft magnetos, the procedure for timing and installing of aircraft magnetos and distributors, and the use of electrical test equipment. This information will enable the ADR to use the proper maintenance procedures which in turn will improve availability, lower operating costs, and make the job easier.

MAGNETO

The DF18LN-2 magneto is a high-tension magneto which employs the principle of stationary coils and a rotating magnet to induce a high voltage.

The DF18LN-2 magneto identification letters and numbers are as follows:

D . . .	Dual (two magnetos in a single housing).
F . . .	Flange type mounting.
18 . . .	Number of cylinders the magneto is designed to fire.
L . . .	Left-hand rotation as viewed from the drive end.
N . . .	Manufacturer's letter designation (Bendix Scintilla).
-2 . . .	Modification number.

This magneto is designed for the R-3350 engine, and its mounting flange is secured with four bolts to the supercharger rear cover. The housing is made of cast-machined aluminum, and cast integral with it are the laminated, soft iron pole shoes and pole shoe extensions. There are four high-tension outlets and four ground outlets in the housing. To provide for cooling, external fins are case on each side of the housing. The nameplate is on the upper side of the magneto near the mounting flange. It includes the type identification letters and numbers, serial number, and manufacturer's part number.

Components

MAGNET.–The magnet serves as the source of magnetomotive force that will induce an electromotive force (emf) in the circuits necessary to produce a spark across the spark plug electrodes. It is commonly referred to as an 8-pole rotating magnet. It is made of Alnico alloy. The poles of the magnet are so arranged that there are four north poles and four south poles. The poles are staggered 45 degrees from each other.

CROSS-SHAFT.–The cross-shaft provides a means for mounting and driving the cam. It is supported in a vertical position, opposite the drive end of the rotating magnet, by two semi-sealed ball bearings. The cross-shaft is turned by a bevel gear which is secured to the cross-shaft by means of a Woodruff key and nut. A small pinion gear drives the bevel gear, and these gears are located in the gear compartment. The gear compartment does not normally require lubrication between overhauls.

CAM.–The purpose of the cam is to insure that the spark occurs at the proper position relative to piston travel. It is secured to the end of the cross-shaft which protrudes from the side of the magneto. The cam is made of chrome-nickel steel and is referred to as a compensated cam. This is because the 18 lobes are unevenly spaced and of different shapes around the cam. The cam is secured to the end of the cross-shaft by means of a vernier ratchet, which allows fine adjustment of the cam for timing.

The vernier ratchet is made up of three parts, which allow for adjustment of the cam for timing purposes. There are five important markings on the cam.

1. Arrow–Direction of rotation.
2. Slot–Identifies No. 1 lobe (fires No. 1 cylinder).
3. Master rod–Master rod location for which cam is compensated.
4. Engine type–Type of engine on which cam is used (R-3350).
5. E-gap–Number of degrees of E-gap for No. 1 cylinder.

NOTE: There is a step cut in the cam which is used to align the cam with the timing post mark when checking timing.

BREAKER PLATE.–The breaker plate provides a means of mounting the breaker points and to preload the cross-shaft bearings. The preload is set at overhaul by shims in the breaker plate. A timing post is cast integral with the breaker plate, and a mark is scribed on this post at a point where the breaker points open at No. 1 E-gap position. An adjustable rack mounted on the breaker plate is used to synchronize the front points to the rear points.

BREAKER POINTS.–The purpose of breaker points is to make and break the primary circuit. They are mounted on the breaker plate. The breaker points are the pivotless type. The contacts are made of platinum iridium, and an arrow on the assembly indicates the direction of run-in. Two friction screws are used to hold the points on the breaker plate, and an eccentric is used to adjust the points.

CONDENSER.–The condenser reduces excessive arcing of the points and aids in obtaining a rapid collapse of the primary field.

INDUCTION COIL.–The induction coil is a nonmechanical device which employs the principles of induction to create a spark to fire the air-fuel mixture in the cylinder.

HIGH-TENSION TERMINAL BLOCK.–The high-tension terminal block serves as a connector between the secondary windings of the induction coil and the high-tension leads.

DISTRIBUTORS

The distributors are located on the nose section and are integral with the harness manifold. They distribute the secondary current, in firing order, by means of a rotating finger. The finger rotates at one-half crankshaft speed, which will give the required spark in each cylinder for every two crankshaft revolutions. The current is delivered from the magneto to the finger via a center contact in the distributor head, after which the finger directs the current to an electrode which is connected to an individual spark plug lead.

HARNESS

The harness is provided to conduct the current from the distributors to the spark plugs through the ignition leads. In the high-tension system, to combat the problem of voltage leakage and prevent interference with the aircraft communication system, it is necessary to provide heavy insulation for the leads and to shield and ground the harness to reduce the interference.

The DF18LN-2 harness provides a path for the secondary current to flow from the electrodes of the distributor to the spark plug of the cylinder, in firing order. The harness manifold is made in three sections and connected together by the distributor covers. (See fig. 9-3). There are 36 lead outlets for attachment of the spark plug lead to the cylinder. The harness is a rewirable type; however, if extensive wiring is required, the harness should be sent to overhaul.

LEADS

Delivery of the high-tension voltage to the spark plug is accomplished through the use

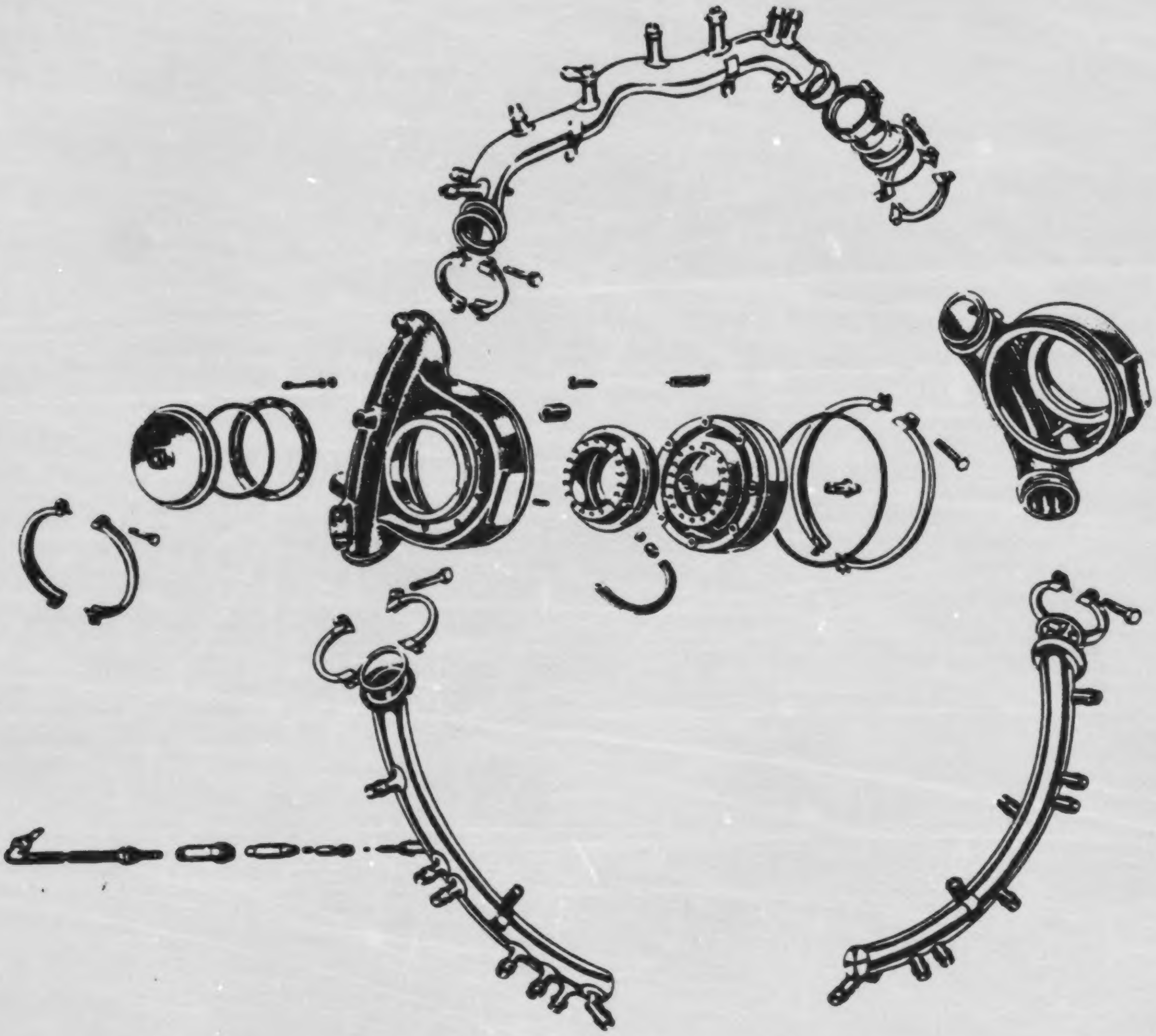

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Figure 9-3.–High-tension ignition harness assembly.

of individual ignition leads. The type of leads used depends on the engine size and whether the ignition system is low or high tension. The high-tension lead in older engines may run from the magneto on the rear accessory pad to the spark plug or, as on the newer model engines, run from the ignition harness or ignition coil on the individual cylinder to the spark plug.

The leads of the DF18LN-2 are in two sections–one from the distributor electrode to the manifold outlet, and the other from the manifold outlet to the spark plug. They are made of seven-strand stainless-steel cable with insulation.

The insulation consists of 1/16-inch-thick rubber directly over the cable. The rubber is covered by a 1/32-inch layer of neoprene. The neoprene in turn is coated with a layer of lacquer. The rubber layer over the cable prevents leakage of current from the cable. The layer of neoprene protects the rubber from oil or gasoline, which whould cause insulation breakdown. The lacquer protects the neoprene and greatly increases the resistance to insulation breakdown.

The spark plug lead, from the manifold outlet, is encased in a flexible radio shielding, which aids in reducing interference in the communication system of the aircraft.

The cable has the date of manufacture stamped on it. The "shelf life" is 36 months from the date of manufacture. If rewiring is required and the age of the cables to be used is over 36 months, it must not be used for aircraft ignition.

Inspection

Inspection of the ignition leads consists mainly of checking the individual leads for integrity of the ferrules, coupling nuts, and shielding; condition of the ceramic terminal sleeves, insulation condition, and the terminal contact spring. They should be checked for chafing, routing, and evidence of cracking due to heat or age.

All ignition leads should be thoroughly checked for the above listed items. If found defective, they should be replaced.

Testing

Testing of the high-tension leads can be accomplished through the use of a high-voltage insulation tester or with an ohmmeter. The primary consideration is that the lead deliver all the voltage to the spark plug. The use of the testing units named previously should remain in the hands of competent personnel who are checked out in the procedures of use and are qualified to accept or reject the material in question. The ADR will learn these methods and procedures as he becomes more proficient in his rating.

Removal

The ignition lead is connected to the spark plug at the cylinder end and to the ignition coil or the ignition harness at the other. Removal of the lead in most cases involves only the spark plug end of the lead. This will occur when the plugs are changed or when troubleshooting the ignition system.

Care should be taken whenever the lead is removed from the spark plug to pull the cigarette (ceramic terminal, if used) from the plug so that neither the ceramic insulation within the spark plug is cracked or broken, nor the cigarette is broken.

Upon installation of the lead, if it has been removed completely, care should be observed to prevent the lead from twisting when it is clamped to the cylinder baffles. Also, install the terminal in the plug with the same care as it was withdrawn and when tightening the coupling nut, do not bend, twist, or distort the elbow. This may cause shorting or grounding of the voltage and render the spark plug inoperative.

OPERATION

The secondary current is conducted from the magneto to the distributors by means of high-tension leads. These leads are attached to the distributor covers. The current is transferred through a high-tension block and electrode in the cover to the distributor finger, from the traveling electrode on the distributor finger to the distributor bowl electrodes, which are attached to individual spark plug leads. The distributor finger is driven at one-half crankshaft speed and is so timed as to fire the cylinder according to manufacturer's specifications.

As these magnetos have a compensated cam with the lobes ground at unequal intervals, the position of the high-tension electrodes in the distributor are also unevenly spaced. Therefore, it is important that the high-tension electrode of the distributor finger be set in the proper relation to the No. 1 distributor electrode. This relation is governed by the timing mark engraved on the distributor mounting pad on the engine. The important phase, then, of the distributor finger timing is to make sure that a portion of the finger electrode will always be over the distributor head electrode when firing takes place from any one of the 18 cam lobes.

GROUND TURNUP AND CHECKS

The ground turnup and check procedure for the high-tension system follow:

Ignition Switch Check

Move the mixture control toward IDLE CUTOFF until the engine rpm drops down to 300 rpm; move the mixture control back to AUTO RICH. The engine should return smoothly to 600 rpm. Make this check with the magneto switch on RIGHT (R) and then on LEFT (L). The engine should be capable of performing this test satisfactorily on either magneto switch position if the magnets and breaker points are in good condition. This test should not be made until the engine is warmed up sufficiently and temperatures are stabilized.

Ignition System Check

The remainder of the ignition system check is essentially the same as that for the low-tension system.

LOW-TENSION IGNITION SYSTEM

The ignition system used on most reciprocating aircraft engines in the Navy is the low-tension system. The low-tension ignition system is favored over the high-tension system for the following reasons: Because of the much shorter high-voltage path in the low-tension system, it is less apt to be affected by moisture and high altitude operation. The low-tension system requires less maintenance, and malfunctions are more easily located than in the high-tension system. Longer spark plug life is obtained with the low-tension system.

The low-tension ignition system, such as that used on the R-3350-32W Wright engine, is comprised of a dual magneto generator, a primary lead conduit containing four primary leads (from the coils in the magneto) and one spark advance relay lead, a starting vibrator lead, a harness, two distributors, nine Y-leads, an ignition switch, four switch leads, a starting vibrator, and spark plugs.

MAGNETO GENERATOR

The DLN+9 magneto generator is mounted on the supercharger rear cover at the rear of the engine. The letter and number designation is as follows:

D–Dual ignition.
L–Left-hand rotation of the magneto.
N–Manufacturer (Scintilla).
9–Modification number.

The magneto is essentially an a-c generator. It contains no secondary windings; therefore, it produces only low-voltage, or low-tension, current. It contains four complete primary circuits, each of which fires nine spark plugs.

The magneto is mounted on the rear case or accessory section of the engine in a horizontal position with the nameplate up, the drain holes facing down, and the electrical connection to the harness facing to the right.

It has the standard flange type mount, and four elongated holes for ease of timing to the engine. The flange is cast with the outer housing and made of aluminum alloy to aid in preventing or reducing radio noise.

There are two drain holes. One is located in the flange to prevent oil or condensation from draining into the magneto generator from the engine. The other drain hole is located in the outer housing to vent the magneto generator to atmosphere.

An inner housing made of cast magnesium alloy fits inside the outer housing. Four sets of pole shoes and extensions are designed as part of the housing. These four sets of pole shoes, combined with the two 4-pole magnets, provide four individual magnetic circuits. A primary coil is mounted across each set of pole extensions, and the coils are interchangeable among themselves, but when they are secured on the extensions, they assume definite designations which are marked on the inner housing.

Two primary coils are mounted horizontally opposite each magnet. The coils mounted opposite the No. 1 magnet are labeled the R1 and the L1 coils; the coils mounted opposite the No. 2 magnet are labeled the R2 and the L2 coils. It is from this source that each circuit of the igntion system receives its designation. The No. 1 magnet produces current in the R1 and L1 coils, and the No. 2 magnet produces current in the R2 and L2 coils. (See fig. 9-4.)

One end of the coil wire is grounded to the housing. The other end is connected to a five-pin cannon plug on the cover.

The magneto generator cover is of cast aluminum alloy and fits tightly on the

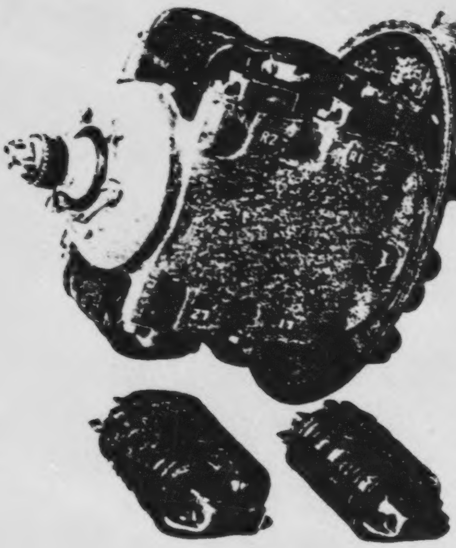

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Figure 9-4.–Magneto generator coil installation.

outer housing to seal the interior of the magneto.

Two 5-pin cannon plug connectors are on the cover, one for connecting the magneto switch to the coils, the other for connecting to the harness.

A timing plunger is also located on the magneto cover and is used to locate the E-gap position. When it is depressed, it will slip into one of four slots milled into the end of the magnet shaft. Each time the timing plunger falls into one of the slots, the magnet will be in an E-gap position for the No. 1 or rear magnet. (See fig. 9-5).

A lip type clamp and four screws hold the cover on the outer housing. The clamp is drawn tight by two screws, which should be tightened to the proper torque value.

The two magnets are mounted on the same shaft and the poles are staggered 45 degrees from each other. Because the coils are mounted horizontally, each E-gap will affect two coils at one time. There are, therefore eight consecutive dual impulses of low-voltage current produced for each revolution of the magneto shaft. Nine dual impulses are needed. Therefore, the magnet shaft is driven at 1 1/8 engine speed on an 18-cylinder engine. The maximum coming-in speed of the magneto generator is 250 rpm, but will more often be near 90 or 100 rpm. Coming-in speed is the speed at which the voltage induced is high enough to fire a 5-millimeter gap evenly and consistently.

DISTRIBUTORS

The purpose of the distributors is to direct the low voltage to the proper high-tension coil units at the proper timed interval to fire a spark plug.

The distributors are mounted on the upper side of the nose section. The left distributor is used to fire all the rear plugs in all cylinders. The right distributor is used to fire all the front plugs in all cylinders.

They are of the conventional flange-mounted design, with three elongated holes in the flange for fine timing to the engine. (See fig. 9-6). The housing is made of aluminum alloy and has a vent in the cover to allow the escape of ozone gases and thereby prevent nitric acid formation. The heat of the arc combines the nitrogen and ozone, and this forms a deposit on the dielectric parts, such as the rotor and segments, and forms a good conducting surface to the nearby grounded parts. By having adequate ventilation, the fumes can be carried away before they have a chance to do any harm.

The distributor cover is secured to the distributor with a clamping ring. The segment plate with the 18 segments arranged in 2 rows of 9 each is bolted in the top of the cover. The segments are insulated from each other, and they have their own primary lead running to a coil unit and then to the spark plug. Also in the cap are three contact springs which, when placed over the distributor, come against a matching bushing in the collector plate. This is how the current enters the distributor.

The two distributors are identical and are interchangeable from right to left.

In the body of the distributor are four sets of breaker assemblies which are actuated by two 9-lobe compensated cams. The two cams compensate for the top center variation which is characteristic of radial engines. Each cam actuates two breaker assemblies; that is, one

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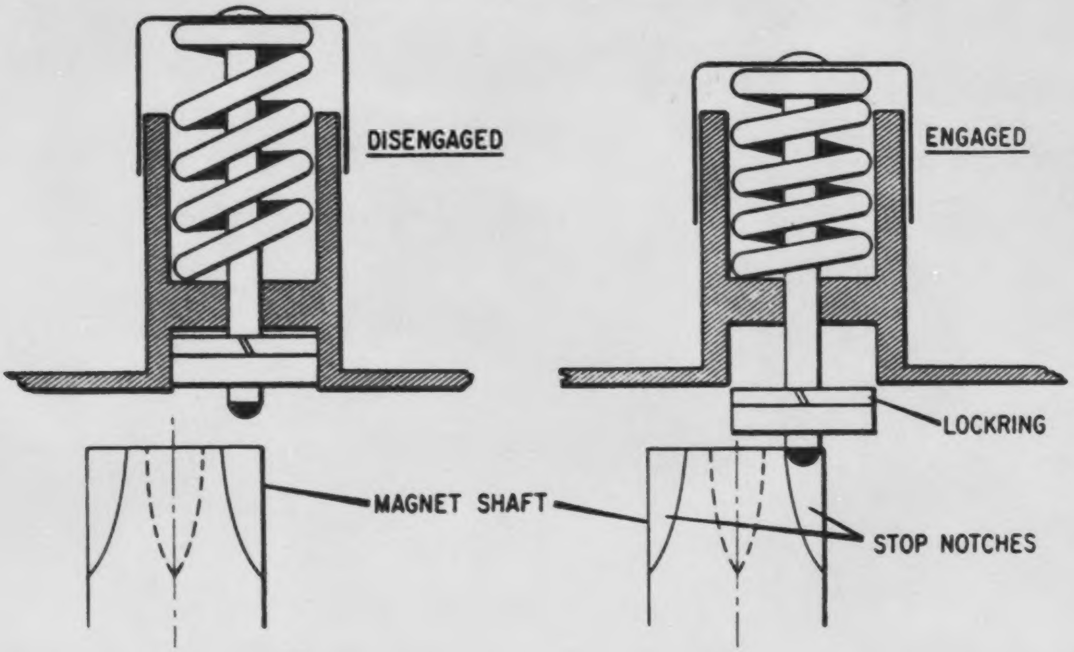

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Figure 9-5.—Magneto generator E-gap plunger.

cam operates No. 1 retard points and No. 2 retard points; the other cam operates No. 1 advance points and No. 2 advance points.

Because these points are of the pivotless type, there is no set clearance; instead a point duration of 22 degrees is used. For proper operation of the points, the spring that holds the cam follower against the cam must be strong enough to eliminate any tendency of the cam follower to skip from lobe to lobe and miss the hollows in between. This is called floating point and will cause a very erratic spark at the plug. The main spring tension should be from 15 to 32 ounces for proper operation. If the spring tension is too great, this will cause the points to bounce.

If current is present in the inner ring of the collector plate, it will be picked up by the brush making contact with the inner ring. As this brush is connected to a brush facing up, that brush will also become energized. It will be making contact with a segment in the outer row of segments, and transfer the current to the particular transformer coil unit at the cylinder. If it should be the outer ring on the collector plate that is energized, the current will be picked up by the brush and transferred to the inner row of segments, and thence to an even-numbered cylinder.

On top of the distributor housing is a composition collector plate with two collector rings—inner and outer. These two rings are insulated from each other and are part of the primary circuit. The No. 1 retard points and No. 1 advance points are electrically connected to the inner collector ring. No. 2 retard and No. 2 advance points are connected to the outer collector ring.

The rotor is secured to the end of the distributor above the collector plate. It carries four carbon brushes under spring tension, two of which extend up from the rotor and two others which extend down from the rotor and make contact with the collector rings on the collector plate. These brushes have a minumum length and are interconnected in pairs.

A distributor cap fits over the top of the distributor and provides the means for getting the current to the spark plugs. Each cap is designed with 18 segments arranged in two rows, nine in the inner row and nine in the outer row. The segments in the inner row are arranged

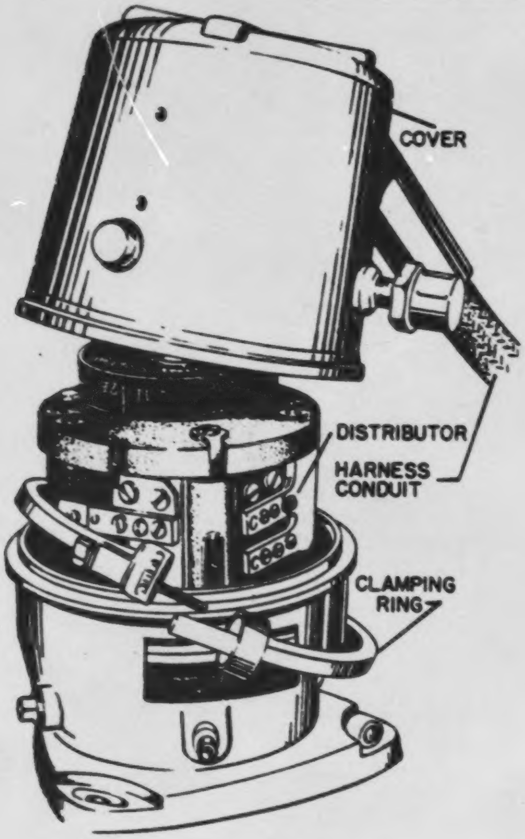

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Figure 9-6.–Distributor and cover.

to send their impulses to the even-numbered cylinders and the segments in the outer row send their impulses to the odd-numbered cylinders.

As long as the breaker points are closed, there are two complete circuits in the system. One is out through the breaker points to ground and back to the grounded primary coil; the other is out through the distributor into the primary windings of the coil unit. The circuit through the points has a lower resistance than that of the circuit through the coil units; therefore, the current will take the path of least resistance through the points as long as they remain closed. When E-gap is reached in the magneto generator and the current flow is at its peak value, the points are opened by the cam and the current suddenly has no place to go but out to the coil units. Because it was interrupted by the points when it was at peak value, it will travel through the coil units as a terrific surge. This surge through the primary coils of the unit induces the high voltage in the secondary to arc across the gap of the spark plug. The duration of the secondary current is very short-lived and falls away quite rapidly.

The two distributors are times exactly together, and when one (right) is firing the front plug in a cylinder, the other (left) is firing a rear plug in that same cylinder.

In the base of the distributor there is a relay which operates two contacts, one for each ignition circuit. Each ignition circuit has an advance breaker and a normal firing (retard) breaker. The advance points are connected directly to ground, and the retard points are grounded through the relay as shown in figure 9-7.

With the relay control switch in the cockpit in the retard position (OFF), no current flows in the relay coil, and spring pressure holds the points in contact with each other. With the relay contacts closed, the primary current in the ignition circuit has a direct path to ground which prevents any interruption of the primary current when the rotating cam opens the advance points.

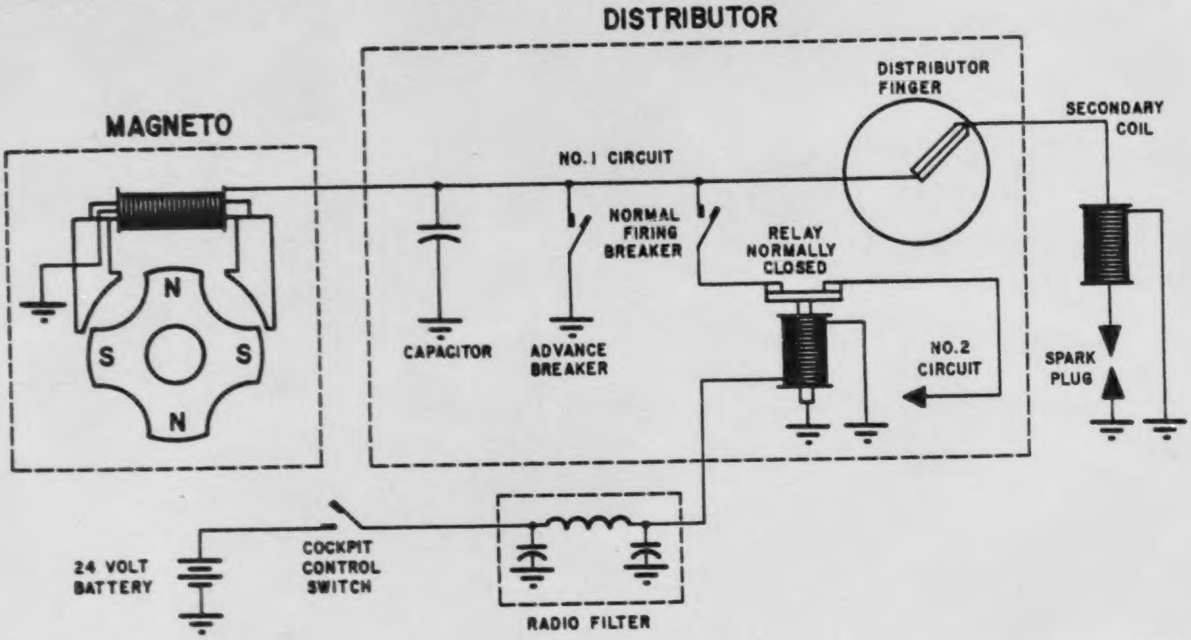
As the breaker cam continues to turn, the retard points are opened and there is an immediate interruption of primary current followed by the normal cycle of ignition events.

With the relay control switch in the advance position, the relay coil is energized and the contacts are separated. The retard points no longer are connected to ground; and when the advance points open, the primary current is interrupted and ignition occurs.

The relay points are held in the closed (retard or normal firing) position by spring pressure. If a relay should fail, the contacts would remain closed and normal firing would take place.

Each of the breaker assemblies must be so adjusted or timed to insure that the current from the magneto generator is allowed to go to the high-tension coil unit at the proper time. The efficiency of the engine power depends very much on the spark being delivered when it will get the maximum horsepower available from each cylinder.

The timing marks on the rotor and collector plate are put there for a purpose. It can be readily seen that if the timing marks on the


DISTRIBUTOR
MAGNETO
N
S
S
N
NO. 1 CIRCUIT
CAPACITOR
ADVANCE BREAKER
NORMAL FIRING BREAKER
RELAY NORMALLY CLOSED
DISTRIBUTOR FINGER
NO. 2 CIRCUIT
SECONDARY COIL
SPARK PLUG
24 VOLT BATTERY
COCKPIT CONTROL SWITCH
RADIO FILTER

AD.69

Figure 9-7.–Schematic diagram of ignition circuit.

rotor do not align exactly with the correct marks on the collector plate at the moment of point opening or closing, the distributor is not timed correctly.

The timing of the distributor rotor to the collector plate is accomplished by use of the vernier ratchet.

The No. 1 mark on the rotor should align with the time open mark on the collector plate when the No. 1 points just start to open on No. 1 lobe and should align with the time close mark just as the points close. The No. 2 points, if timed properly, will also open when the No. 2 mark on the rotor aligns with the time open mark on the collector plate and will close when the mark on the rotor aligns with the time close mark.

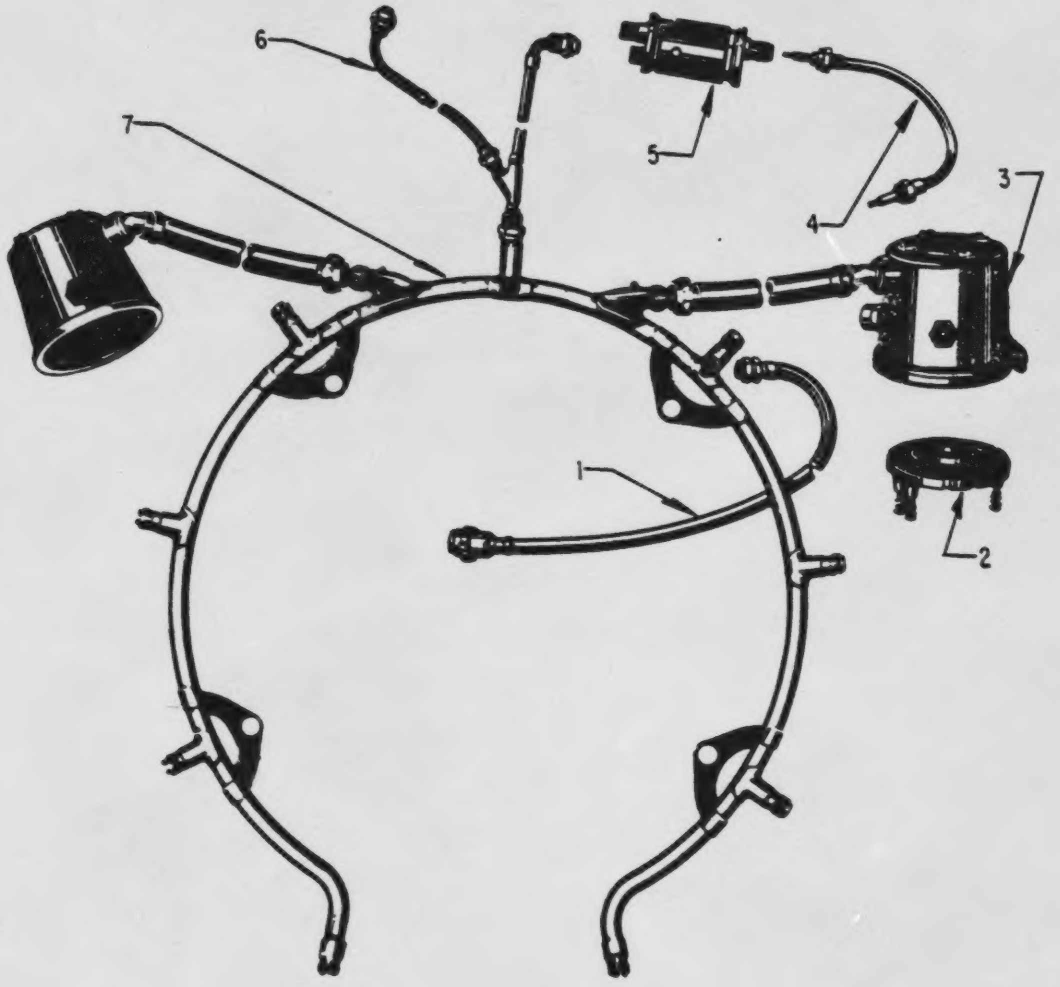
It is very important that the points open at the correct time in relation to the time of the magnetic position in the magneto generator, which has been installed at the engine firing position. Keep in mind that when we ratchet the rotor, we are also positioning the carbon brushes so that they will align with the proper segments when we install the cover on the distributor. This will make the whole ignition system in time with the engine.

HARNESS

The low-tension harness is different from that of the high-tension harness in that it carries only low-voltage current. The purpose of the harness is to conduct low-voltage current from the magneto generator to the ignition coil units, located on the cylinders, via the distributors and primary (Y) leads.

The complete harness assembly consists of the magneto to harness lead, tubular harness, distributor covers, primary (Y) lead assemblies, ignition coil units, and the spark plug leads. These are shown in figure 9-8.

The MAGNETO TO HARNESS LEAD (fig. 9-8, item 1) is a 5-pin cannon plug lead. Pins A, B, C, and D conduct primary current from the magneto generator's primary coils to the distributors. Pin E provides a path for 28 volts direct current to the distributors for spark advance operation.



AD.70

1. Magneto generator to harness lead.
2. Distributor segment plate.
3. Distributor cover.
4. Spark plug lead.
5. Ignition coil unit.
6. Primary (Y) lead.
7. Harness.

Figure 9-8.—Low-tension ignition harness assembly.

The HARNESS is tabular constructed and has 23 primary wires routed through it. Included are four primary leads from the magneto generator, one lead for the 28-volt direct current to operate the spark advance relay, and 18 primary leads directing primary current from the distributor segment plate to the outlets for Y lead connection. Around the harness are 12 connecting points—two for distributor cover connection, one for magneto to harness lead connection, and nine for primary (Y) lead connection. (See fig. 9-8, item 7.)

The DISTRIBUTOR COVERS, as mentioned earlier, are an integral part of the harness and have a segment plate bolted to the top of them. The segment plate has 18 segments arranged in two rows of nine each. Attached to each segment is a primary lead, which is routed through the harness to a Y lead connecting point. As previously stated, they are insulated from each other. They are also numbered 1 through 18, inner row even numbered and outer row odd numbered. Do not mistake the numbering for engine firing order–refer to table 9-1 and figure 9-9.

There are also three contact pads on the segment plate, labeled P1, P2, and BO. Pads P1 and P2 receive primary current from the magneto generator and transfer it to the distributor by means of a contact spring on the bottom of the segment plate (fig. 9-8, item 2). The BO pad receives 28 volts direct current and transfers it to the spark advance relay in the same manner as P1 and P2 does.

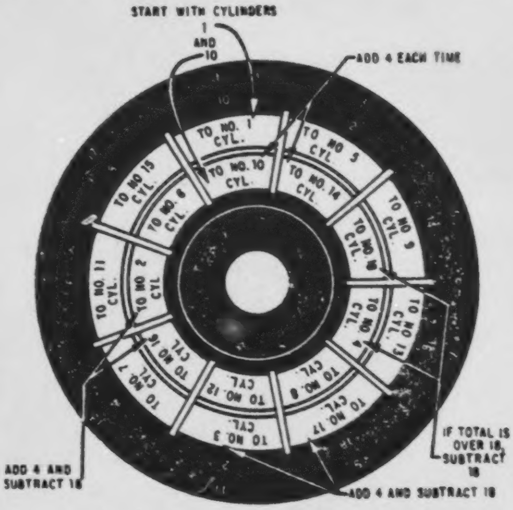
The PRIMARY (Y) LEAD (fig. 9-8, item 6) is a shielded construction with four primary wires routed through it. It is constructed in the shape of a Y, with two primary leads routed through each fork of the Y. The 4-pin end connects to the harness and the 2-pin ends each connect to an ignition coil unit. The Y lead is not a rewirable lead; therefore, it must be replaced when a malfunction occurs.

IGNITION COILS

Each coil unit contains two transformers, each transformer consisting of a primary winding, a secondary winging, and a coil core. It is here that the low-tension current is converted to the high-tension current required for ignition. A coil unit is mounted on each cylinder of the engine, furnishing high-tension current to the two spark plugs of that cylinder. A high-tension (coil-to-spark plug) lead carries the current from the coil units to each spark plug. A coil unit is shown in figure 9-10.

Table 9-1.–Segment numbering related to firing order.

ODD		EVEN	
Segment No.	Firing order	Segment No.	Firing order
1	1	2	12
3	5	4	16
5	9	6	2
7	13	8	6
9	17	10	10
11	3	12	14
13	7	14	18
15	11	16	4
17	15	18	8


START WITH CYLINDERS
1
AND
10
ADD 4 EACH TIME
TO NO. 1 CYL.
TO NO 5 CYL
TO NO. 10 CYL.
TO NO. 14 CYL.
TO NO 15 CYL.
TO NO. 6 CYL.
TO NO 9 CYL.
TO NO 18 CYL.
TO NO. 11 CYL.
TO NO 2 CYL
TO NO 13 CYL.
TO NO 4 CYL.
TO NO 16 CYL
TO NO 7 CYL
TO NO. 12 CYL.
TO NO. 8 CYL.
TO NO 3 CYL.
TO NO. 17 CYL.
IF TOTAL IS OVER 18, SUBTRACT 18
ADD 4 AND SUBTRACT 18
ADD 4 AND SUBTRACT 18

AN EASY WAY TO DETERMINE THE DISTRIBUTOR SEGMENT CONNECTIONS WHEN YOU DO NOT HAVE A CHART FOR REFERENCE.START WITH SEGMENTS 1 AND 10, WHICH FIRE CYLINDERS 1 AND 10 RESPECTIVELY,WORK CLOCKWISE ADDING FOUR EACH TIME TC OBTAIN THE NEXT CYLINDER TO FIRE.

AD.71

Figure 9-9.–View of DLN-9 distributor segments, illustrating segment numbering and cylinder firing relation.

SPARK PLUG LEADS

The spark plug lead (fig. 9-8, item 4) conducts the secondary current from the ignition

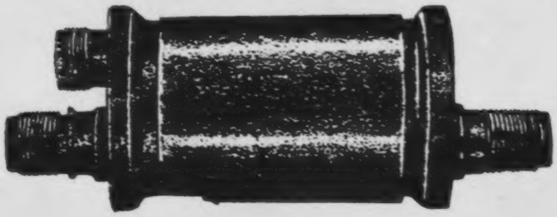


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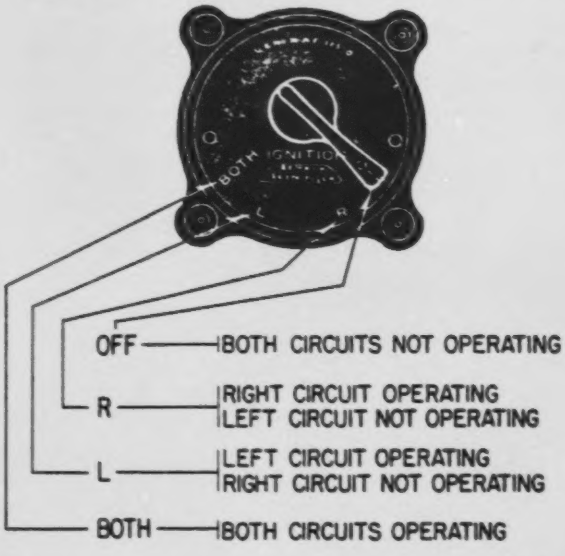
Figure 9-10.–Ignition coil unit.

coil unit to the spark plug to be fired. The low-tension spark plug lead is much shorter than that of the high-tension system; therefore, it does not allow dissipation of the current from the coil unit to the spark plug. The end results are a hotter spark at the plug and less fouling of the spark plugs.

SWITCH

The magneto primary circuits are wired through an ignition switch which gives the pilot control of the ignition system and enables him to check for proper operation of each magneto system. There are four positions on an aircraft magneto switch-OFF, L (left), R (right), and BOTH. One side of the switch is connected to ground. When the switch is in the OFF position, it is closed, connecting the four primary coils. of the magneto to ground. When the switch is at BOTH, this circuit is open and the primary coils are no longer grounded through the switch. In the R position, the primary coils which supply current to the left distributor are grounded; in the L position, the primary coils which supply current to the right distributor are grounded. Therefore, when the pilot switches to R, the engine is running on the right distributor, and the pilot can check for normal operation of that circuit. With the switch in the L position, operation of the other half of the ignition system can be checked. An ignition switch for a single engine aircraft is shown in figure 9-11.

An ignition switch designed for twin-engine aircraft is shown in figure 9-12. This switch combines two switches of the type shown in figure 9-11, with the addition of a push-pull knob which operates the master emergency ignition switch. When the knob is pulled out to the OFF position, all ignition is cut off regardless of the position of the switch levers. In an emergency, all ignition for both engines can be cut off by one movement of the push-pull knob to the OFF position.


BOTH
IGNITION
L
R
OFF — BOTH CIRCUITS NOT OPERATING
R — RIGHT CIRCUIT OPERATING / LEFT CIRCUIT NOT OPERATING
L — LEFT CIRCUIT OPERATING / RIGHT CIRCUIT NOT OPERATING
BOTH — BOTH CIRCUITS OPERATING

AD.73

Figure 9-11.–Single engine ignition switch.

When switching from BOTH to either R or L, normal operation is indicated by a loss of engine rpm. The amount of drop to be expected varies with the engine and the allowable maximum drop can be found in the flight manual of the engine concerned. If no drop in rpm occurs, it indicates that the primary coil of the magneto is not being grounded. This is a dangerous condition because the pilot would no longer have positive control of the magnetos. This would be of particular importance in an emergency where the pilot would have to cut the ignition, as in a crash landing. It is also dangerous even with the engine not running, as anyone moving the propeller would be exposed to the danger of the engine kicking over, since one magneto circuit is still ON. Although all Navy piston-engined aircraft have some form of idle cutoff system in the carburetor, it is very important that the switch be capable of grounding the magneto.

The normal rpm drop that occurs when switching from BOTH to either R or L is due to the changed conditions in the combustion chambers. With the switch on either R or L, one-half of the magneto is grounded and only the row of plugs served by the other half of the magneto is firing. The charge is being burned by a single point of ignition and therefore requires a longer time to burn. The resulting slight loss of power is indicated by the loss in rpm. If the loss is greater than the allowable maximum, usually 100 rpm, it indicates a malfunction of the magneto, distributor, harness and wiring, or spark plugs.

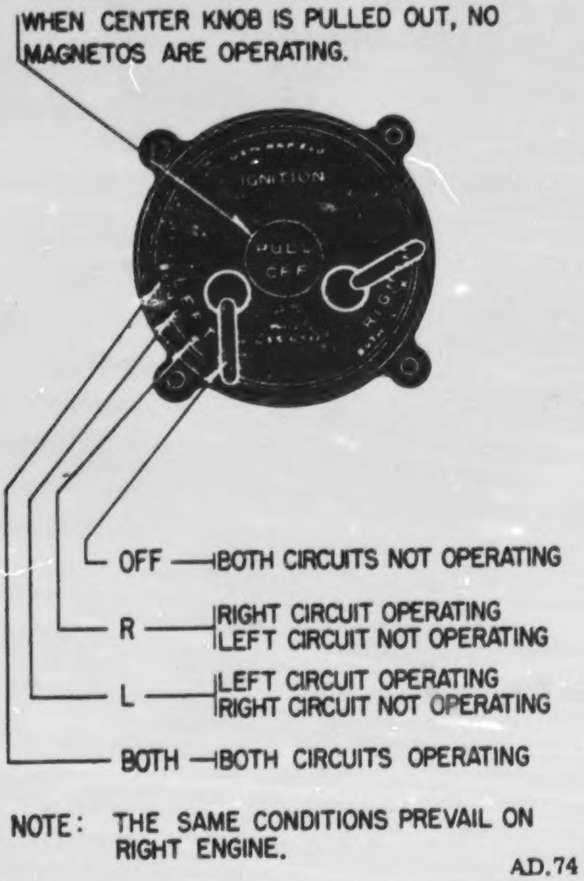

WHEN CENTER KNOB IS PULLED OUT, NO MAGNETOS ARE OPERATING.
IGNITION
PULL OFF
LEFT
RIGHT
OFF —BOTH CIRCUITS NOT OPERATING
R —RIGHT CIRCUIT OPERATING
LEFT CIRCUIT NOT OPERATING
L —LEFT CIRCUIT OPERATING
RIGHT CIRCUIT NOT OPERATING
BOTH —BOTH CIRCUITS OPERATING
NOTE: THE SAME CONDITIONS PREVAIL ON RIGHT ENGINE.
AD.74

Figure 9-12.–Dual engine ignition switch.

STARTING VIBRATOR

When turning with the starter to start the engine, the rotational speed of the magneto or magneto generator is too slow to produce sufficient voltage at the spark plug gap to fire the plug. Therefore, provision must be made to supply the engine with the required voltage to start the engine. The starting vibrator receives low voltage current from the battery to aid in starting the engine.

When the starter switch is closed, battery current closes the relay contacts. Then battery current flows through the vibrator coil. The closed vibrator contacts the closed contacts of the relay and the magneto primary coil. As current flows through the vibrator coil, the iron core becomes magnetized and causes the vibrator points to open. In doing so, the battery current is interrupted. As a result, the core of the vibrator coil loses its magnetism, and the vibrator points are again closed by the action of a spring. Again current flows through the vibrator coil and the magneto primary, and the process is repeated. When the vibrator points open, current stops flowing; when they close, current flows. Since these points are alternately opened and closed there is an interrupted flow of current in the magneto primary. This interrupted current produces voltage impulses in the magneto primary much like the magneto does when it is operating. The resultant voltage produced in the magneto secondary is distributed in the same manner as the magneto spark. See figure 9-13 for schematic of starting vibrator circuit.

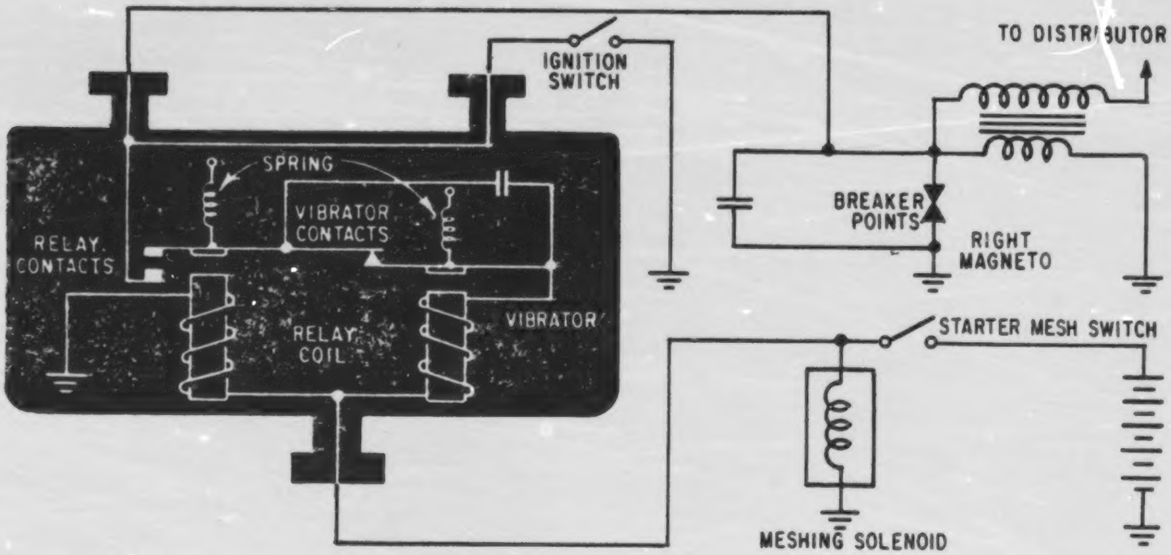
MAINTENANCE

Maintenance of the ignition system, regardless of the size of the engine or the make of the components in the system, is of importance to the mechanic. There are a number of checks that can be made prior to and after periodic inspections, during ground operations, and in the air (if an analyzer is installed). These checks make it possible for the mechanic to locate the source of specific discrepancies. Failure to pass these checks will usually pinpoint the defective component.

The ignition system must deliver, in firing order, and at a predetermined number of degrees ahead of the power stroke in the individual cylinder, high-voltage current to the spark plugs of each cylinder in the engine. The voltage output of the ignition system must be such that the spark will jump the gap at the electrodes under any and all operating conditions.

The two types of ignition systems discussed in this chapter consist primarily of a magneto, distributors, ignition harness, spark plugs, and ignition switches. Proper maintenance is an absolute necessity, as some of the component parts of the ignition system operate at high rates of speed requiring a fine degree of accuracy in maintenance so that the air/fuel mixture in the cylinder may be ignited at the correct instant to develop the right amount of power at all operating speeds of the engine.

Each of the units named may develop conditions where a higher or lower resistance than



AD.75

Figure 9-13.—Starting vibrator circuit.

normal could occur and thus affect engine operation. Some of these conditions that may happen are as follows: The breaker points do not open far enough; the gaps between the distributor rotor and the harness electrodes are too large; oily terminals or carbon tracking. High or low resistances may be due to poor or damaged cigarettes (ceramic terminal) on the high tension leads; and spark plug gaps have too little or too much clearance.

To obtain correct engine performance and power, the internal timing of the magneto must be correct. The internal timing of the magneto consists of the breaker point opening interval in relation to the position of the rotating magnet. The position of the rotating magnet when the breaker points open on the No. 1 lobe of the cam is determined when the magnet E-gap marks on the timing post and the cam step are aligned. Magneto-to-distributor-to-engine timing will also affect the power and the performance of the engine. The breaker point opening must be timed to the specified position of the engine crankshaft so that the spark will occur at the spark plug gap at the correct instant.

REMOVAL AND INSTALLATION OF COMPONENTS

The timing of the magneto and distributors is generally considered to be a part of the installation procedure; however, to simplify the discussion, the timing procedure is discussed in the section following the removal and installation procedure.

Removal of Magneto Generator

Disconnect the ignition switch lead and the main primary lead at the magneto. Place protective covers over the connections on the magneto. Remove the magneto attaching nuts and washers and remove the magneto. Remove the gasket, if used.

Installation of Magneto Generator

Insure that the magneto has been inspected for correct assembly and operation and that the drive shaft nut is tight and cotter keyed. The piston in No. 1 cylinder should be set at the prescribed number of degrees before top center on the compression stroke. If a gasket is used, install a new one on the magneto mounting pad. Remove the spring clip from the timing plunger on the magneto cover. Depress the plunger and turn the magneto shaft until the plunger drops into one of the four notches in the magneto shaft. This insures the correct E-gap position for the magneto shaft. The plunger must be held in while the magneto is being installed. (See fig. 9-14.)

If the drive splines do not mesh, remove the magneto and rotate the magneto shaft 90 degrees so the plunger bottoms in the next slot on the magneto shaft. Again install the magneto. Continue this process of rotating the magneto shaft until the splines will engage and the studs are in the approximate center of the magneto mounting flange slots. Hold the magneto in this exact position and secure with the attaching nuts and washers.

Check to make sure the magneto is mounted properly. One man should turn the propeller in the direction opposite normal rotation and then bring it forward slowly in the direction of rotation until the piston is at the prescribed number of degrees before top center on the compression stroke. If the propeller has been removed, a special turning tool is used. Meanwhile, another man should push in on the timing plunger. If the installation is correct, the plunger will drop into the slot just as the piston reaches the prescribed number of degrees before top center. Torque the magneto attaching nuts.

Reinstall the spring clip on the timing plunger. Remove the protective covers from the magneto connections. Connect the switch conduit first, then the harness conduit. Lockwire the connections.

Removal of Distributor

Loosen the distributor cover to distributor clamping ring. Remove the distributor cover, being careful not to damage the segments in the cover or the carbon brushes on the distributor.

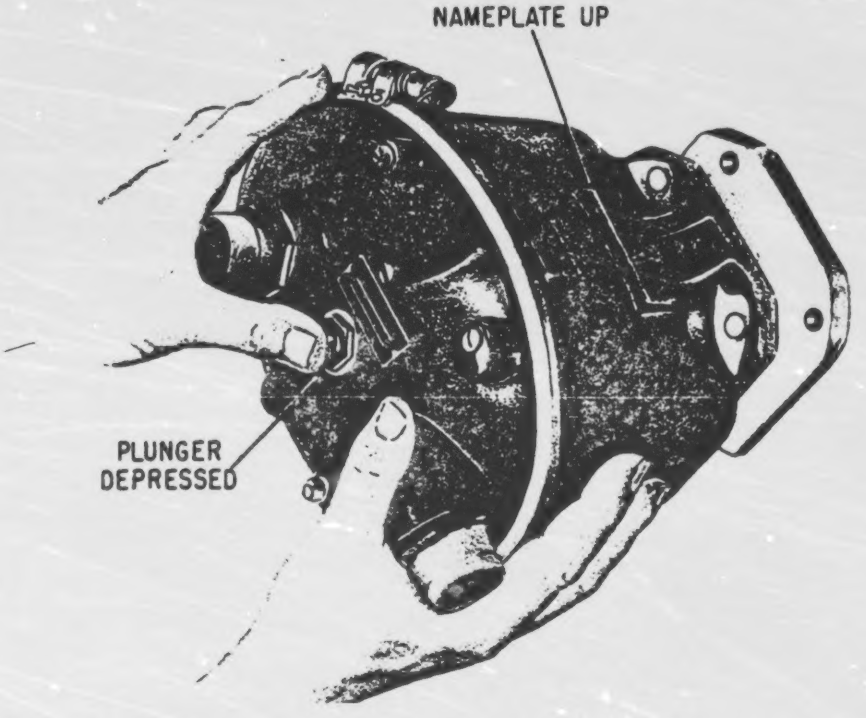


Figure 9-14.–Installing magneto on engine.

Install protective covers at once on both the distributor and the distributor cover. Attach the distributor cover to a convenient engine part temporarily with lockwire to avoid interference when removing and installing the distributor. Remove the distributor attaching nuts and remove the distributor from the engine.

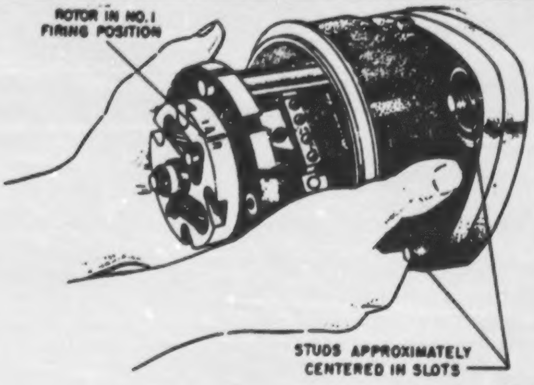
Installation of Distributor

Before installing a distributor, always check the master rod designation plate on the distributor against the engine data plate to see that the distributor has the correct cams corresponding to the master rod location in the engine. Do not remove the protective covers until the distributor is actually ready for installation.

First, rotate the engine in its normal direction until the No. 1 cylinder is at the normal firing position, as prescribed in the engine manufacturer's instructions. This is the same engine position you used for installation of the magneto.

Remove the clamping ring and take off the protective cover from the distributor. Rotate the distributor shaft until the line marked "1R" on the rotor is lined up with the line marked TIME OPEN on the collector plate. Keeping the shaft in this position, install the distributor on its pad so that the studs are approximately in the middle of the elongated holes in the distributor mounting flange. (See fig. 9-15.) If the studs are not approximately in the center of the elongated holes, remove the distributor from the pad. Using the proper tools, remove the securing nut from the drive end of the distributor shaft. Shift the drive gear one tooth on its spline; then put the nut on and put the distributor in place on the pad again. Be sure the rotor is still lined up with the "1R" position. Recheck the position of the studs in the elongated flange holes. If necessary, shift the drive gear again on its splines until the distributor can be mounted in the proper position. When the right setting for the drive gear is found, take the distributor off the pad, tighten the end nut, and install a new cotter pin in the castellated nut. Put the distributor back on the pad and install the holddown nuts. Do not tighten the holddown nuts until the distributor has been timed to the engine and to the other distributor.

After the timing procedure is completed, replace the distributor cover, and put the clamping ring in place. Tighten the clamping screw to the proper torque. Lockwire the screw to the holes provided in the clevis of the clamp bracket. Some types of distributors contain two small plugs, one of which is solid and one of which has a drain hole. If necessary, interchange the positions of these plugs so that the one with the hole is on the underside of the distributor, in order to provide drainage for any oil or water which might enter the unit.


ROTOR IN NO. I FIRING POSITION
STUDS APPROXIMATELY CENTERED IN SLOTS

AD.77

Figure 9-15.—Correct positioning of the distributor on the mounting pad.

TIMING

When a mixture of air and fuel is admitted into the cylinder and compressed, the next step in the cycle of operation is the ignition of the compressed charge at the correct time. The ignition system furnishes high voltage periodically to the spark plug gap at a predetermined position of piston travel in the cylinder. Magneto operation is timed to the engine so that a spark occurs only when the piston is on the proper stroke and at a specified number of degrees before top dead center. The distributor routes the generated voltage to the various cylinders in the firing sequence of the engine.

Magneto (High-Tension)

Before installing a magneto, always make sure that it has been properly checked and inspected. It is assumed that the magneto has been correctly internally timed and synchronized prior to installation. All adjustments for timing must be made at the drive end of the magneto.

In order to time the magneto to the engine, the following steps should be followed:

1. Turn the engine crankshaft until the piston of the No. 1 cylinder is in the firing position on the compression stroke in accordance with the engine manual. This position may be determined with a piston position indicator.

2. Remove the magneto breaker cover and disconnect the primary (P) leads for safety purposes and proper timing light operation; then turn the magneto drive shaft to the position where a straight edge held against the step of the cam lines up with the timing mark on the breaker plate post. At this position the breaker contact points will be just starting to open on the No. 1 lobe of the breaker cam.

NOTE: If the straightedge does not align with the mark within one sixty-fourths inch when the contact points open, do not attempt to correct it by adjusting the contact points. Return the magneto to the bench and recheck the internal timing.

3. Install the magneto on the engine in this position, engaging the drive coupling in such a way that the contact points can be opened by turning the complete magneto in the direction OPPOSITE to that indicated by the rotation arrow on the magneto housing. The elongated slots in the mounting flange provide for this adjustment. Set the magneto at the position where the breakers are just on the instant of opening on the No. 1 lobes, at which position a straightedge held against the cams must line up with its corresponding timing mark.

4. Use a timing light to determine the position where the contacts start to open. The use of a feeler gage between the contact points should be avoided.

5. A variation in synchronization of one-half degree was permitted in setting the breakers at the time the magneto was assembled. This may result in a barely perceptible difference between the opening of the two breakers when checked with the timing light in the above procedure. This small variation will not affect the operation of either the engine or the magneto.

6. Always make sure that the straightedge lines up with the timing mark for the cam at the No. 1 firing position because this mark will be used later in maintenance procedures as a reference for adjusting the contact points. When the magneto has been set at the correct position, tighten the mounting nuts, making sure the magneto does not shift when the nuts are tightened.

7. As a final check turn the crankshaft backward about 30 degrees and then forward until the contact points are just starting to open on the No. 1 lobes of the cam (use timing light). The engine should now be at its exact No. 1 firing position, and a straightedge placed on the breaker cam should line up with the mark on the breaker plate timing post.

8. Reconnect the primary (P) leads and then install the magneto breaker cover.

Magneto Generator (Low-Tension)

The magneto is internally timed at the factory or at overhaul and is never adjusted in the field.

For efficient operation of the ignition system, the magneto should be installed at the E-gap position to coincide with the engine firing position.

The first step is to rotate the engine shaft in its normal direction until the piston of No. 1 cylinder is in the normal firing position on the compression stroke. The piston position indicator should be used for this operation.

Rotate the magneto shaft until the timing plunger bottoms in one of the slots on the magneto shaft, locating one of the four E-gap positions of the No. 1 magnet. Install the magneto on the mounting pad of the engine. If the magneto shaft splines will not mesh with the splines in the engine, rotate the magneto shaft to the next E-gap position, and again attempt to install the magneto. Keep the plunger bottomed until the magneto has been secured. (See fig. 9-14.)

Put the magneto in place and check again. Continue this process of rotation of the magneto shaft until the splines engage. Then hold the magneto in this exact position and tighten the stud nuts which secure the magneto to the engine, using the proper torque for these nuts. The elongated slots will take up any small amount of error in meshing the splines of the magneto generator.

To check and be sure that the magneto is mounted in the right position, slowly rotate the engine shaft until it reaches the normal firing position for No. 1 cylinder. Push in on the timing plunger; if your installation is correct, the plunger will bottom.

Remove the protector covers from the cannon plugs and connect the leads from the harness and switch. Turn the spanner nuts until tight and then lockwire. Install the safety clip on the timing plunger.

Distributors (High-Tension)

There are several different types of high-tension ignition system distributors. The type of distributor and its method of timing discussed in the following paragraphs is the tubular type harness and distributor.

To time the distributor to the engine, it will be necessary to loosen the housing and remove some of the spark plug leads attached to it. The housing is loosened by removing the base clamp ring and loosening the manifold clamp rings. Then the distributor housing is pushed back to expose the distributor finger.

The next step in distributor timing procedure is to remove the distributor finger to expose the nut which locks the drive coupling. Then loosen the coupling nut and install the distributor timing tool. Rotate the coupling unit against normal rotation until the edge of the timing tool is in line with the scribed line on the parting surface. Tighten the coupling nut in this position after all backlash has been removed from the distributor drive gears. The timing tool can now be removed and distributor finger installed.

The distributor housing assembly can now be placed in position on the distributor base. Secure all clamp rings on the distributor and install the spark plug leads that were removed. The distributor can now be lockwired as necessary.

Distributors (Low-Tension)

Before installing a distributor, it is always advisable to compare the master rod designation plate on the distributor with the engine data plate to see that the distributor has the correct cams corresponding to the master rod location of the engine.

Locate the No. 1 piston at the firing position as prescribed by the engine manufacturer's specification.

Remove the clamping ring and take off the protective cap from the distributor. Rotate the distributor shaft until the No. 1R mark on the rotor is aligned with the time open mark on the collector plate. Keeping the rotor in this position, install the distributor on its mounting pad so that the securing studs are approximately in the middle of the elongated holes in the mounting flange. (See fig. 9-15.)

If the studs are not in the center of the slots, remove the distributor from the pad. With a 5/8-inch socket and a 17-tooth spline wrench, remove the securing nut from the drive end of the distributor shaft. Shift the drive gear one tooth on its spline; then put the distributor in place on the pad again. Be sure the rotor is still aligned with No. 1 and open. Check for mounting studs centered in elongated holes. If necessary, shift the drive gear again on its splines until the distributor can be mounted in the proper position. When the right setting has been found, tighten the end nut and install a new cotter pin. Put the distributor back on the pad and screw on the holddown nuts. Do not tighten them now.

Connect timing light with red lead to the connecter strip for No. 1R service points. The other lead is attached to the housing. Now carfully rotate the distributor clockwise on its mounting pad until the timing light indicates that the points are just opening. Holding the distributor in this position, tighten the flange nuts.

NEON type light—Light has just come on, indicating points have just opened. FILAMENT type light—Light has just gone out, indicating points have just opened.

In mounting the second distributor on the engine, follow the same procedure as for the first. Then connect the timing light with a red lead to No, 1R service points of each distributor and the black lead to ground. (See fig. 9-16.)

Then back up the engine through No. 1 firing position to see if both No. 1R points are opening at the same instant; if not, turn the second distributor slightly on its mounting pad until both sets of points are opening at exactly the same instant, which must also be the instant the No. 1 cylinder is ready to be fired. If installing only one distributor, be sure it is timed exactly to the one already on the engine. It must also have the same type of spark advance mechanism.

Replace the distributor head and put the clamping ring in place. Tighten the clamping

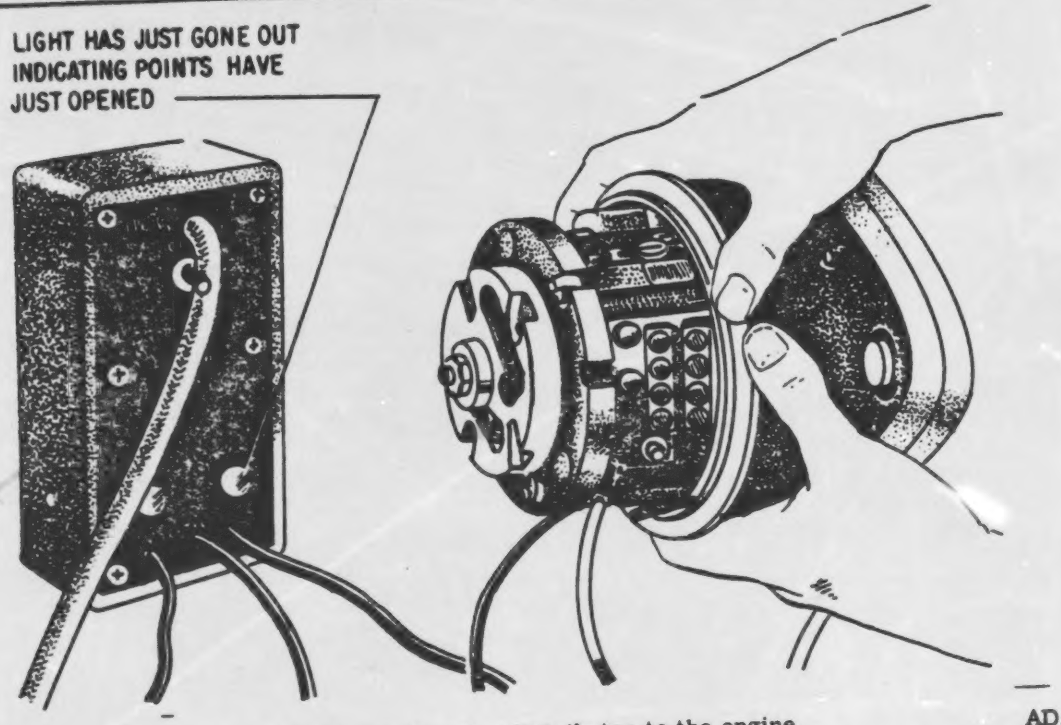


Figure 9-16.–Timing the distributor to the engine. AD.78

screw to 30 inch-pounds torque, and lockwire the screw to the holes provided.

If necessary, interchange the position of the small plugs located in the lower portion of the distributor so that the one with the hole is on the lower side of the distributor to provide drainage for any oil or water that would enter the unit.

INTERNAL TIMING OF THE MANUAL ADVANCE DISTRIBUTORS.–The timing marks on the rotor and collector plate of the manual advance type distributor are shown in figure 9-17. This distributor should be checked for the timing of the following events:

1. No. 1 advance points OPEN.
2. No. 1 advance points CLOSE.
3. No. 1 retard points OPEN.
4. No. 1 retard points CLOSE.
5. No. 2 advance points OPEN.
6. No. 2 advance points CLOSE.
7. No. 2 retard points OPEN.
8. No. 2 retard points CLOSE.

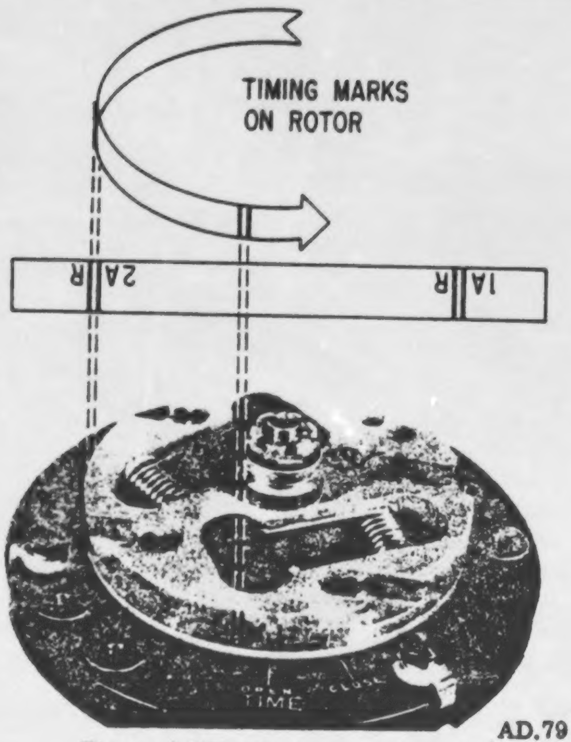
To get an indication of breaker point action with the timing lights, osilate the advance breaker assemblies from the retard breakers by disconnecting the spacers which connect the breaker supports.

The No. 1 advance points should open when the 1A mark on the rotor is aligned with the OPEN mark on the collector plate. (See fig. 9-18.) Turn the rotor in the normal direction of rotation. The No. 1 advance points should close when the 1A mark on the rotor is aligned with the CLOSE mark on the collector plate. (See fig. 9-19.)

The No. 1 retard points should open when the 1R mark on the rotor is aligned with the OPEN mark on the collector plate. (See fig. 9-20.) The No. 1 retard points should close when the 1R mark on the rotor is aligned with the CLOSE mark on the collector plate. (See fig. 9-21.)

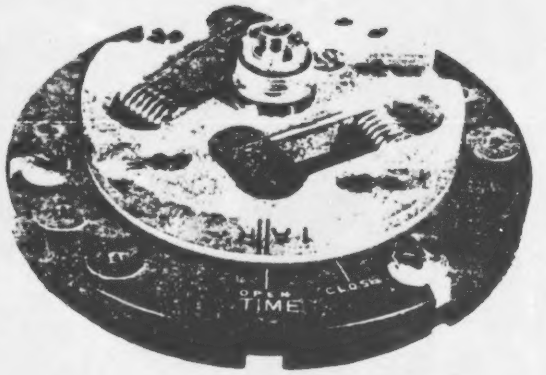
The No. 2 advance points should open when the 2A mark on the rotor is aligned with the OPEN mark on the collector plate. (See fig. 9-22.)

Turn the rotor in the normal direction of rotation. The No. 2 advance points should close with the 2A mark is aligned with the CLOSE mark on the collector plate. (See fig. 9-23.)


TIMING MARKS ON ROTOR
2A R
1A R
OPEN
TIME
CLOSE

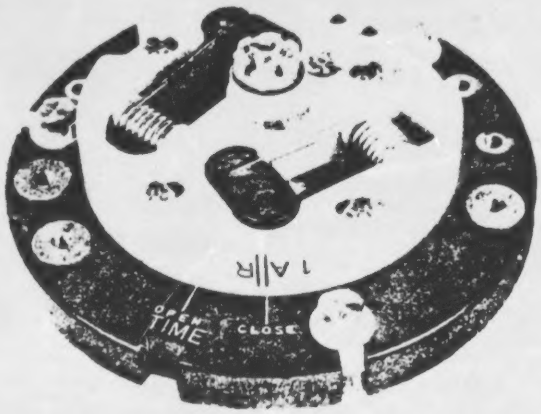
AD.79

Figure 9-17.–Timing marks on the rotor and collector plate of the manual advance type distributor.


1 A R
OPEN
TIME
CLOSE

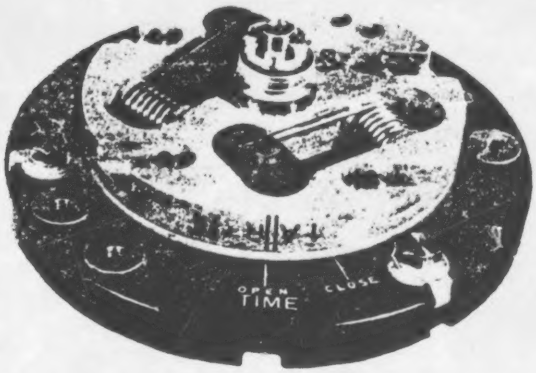
AD.80

Figure 9-18.–Position of No. 1 advance points OPEN.


1 A R
OPEN
TIME
CLOSE

AD.81

Figure 9-19.—Position of No. 1 advance points CLOSE.


1 A R
OPEN
TIME
CLOSE

AD.82

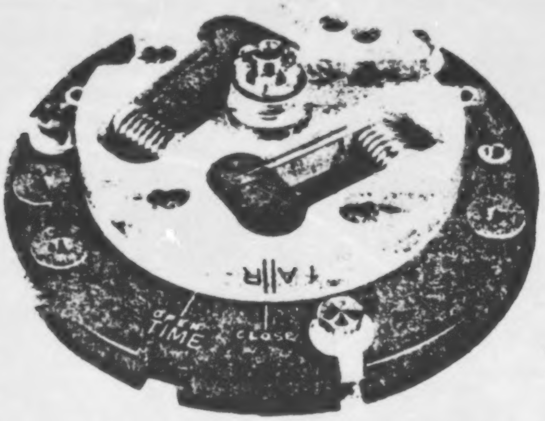
Figure 9-20.–Position of No. 1 retard points OPEN.

The No. 2 retard points should open when the 2R mark on the rotor is aligned with the OPEN mark on the collector plate. (See fig. 9-24.) Turn the rotor in the normal direction of rotation.

The No. 2 retard points should close when the 2R mark on the rotor is aligned with the CLOSE mark on the collector plate. (See fig. 9-25.)

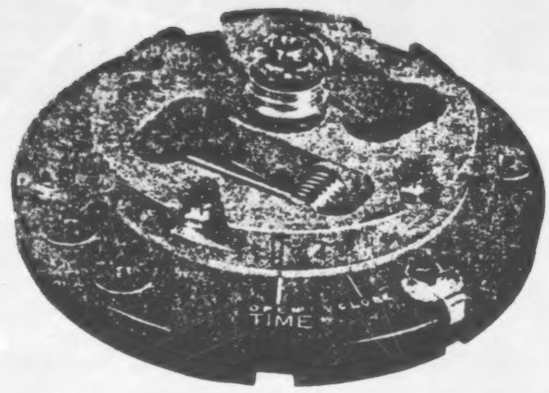
NOTE: Reconnect the spacers between the breaker supports.

NOTE: If the breaker point setting is changed on either type of low-tension distribu-



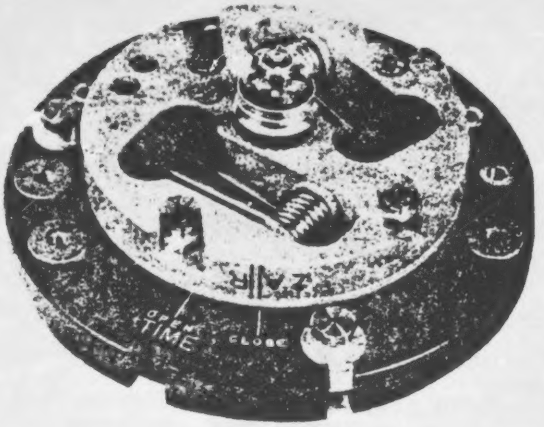
AD.83

Figure 9-21.—Position of No. 1 retard points CLOSE.



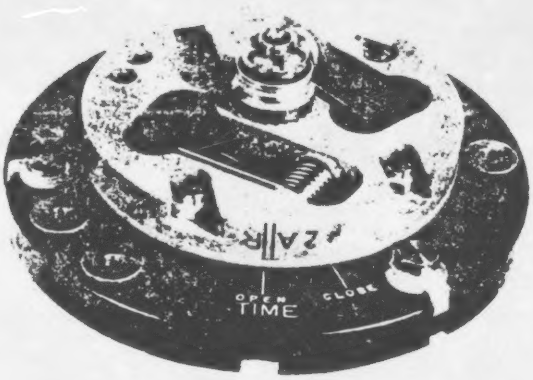
AD.84

Figure 9-22.–Position of No. 2 advance points OPEN



AD.85

Figure 9-23.–Position of No. 2 advance points CLOSE.



AD.86

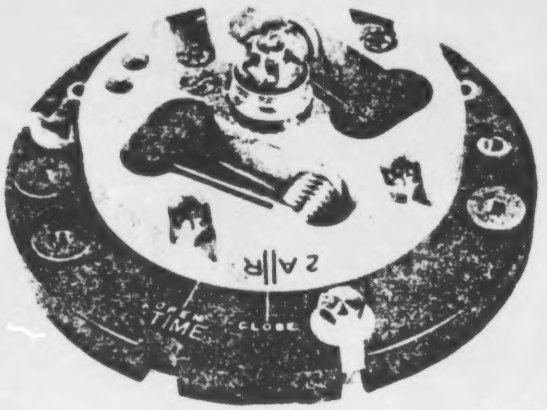
Figure 9-24.–Position of No. 2 retard points OPEN.

tor, the point duration will be affected, and the distributor must be retimed in accordance with overhaul instructions.

TIMING THE MANUAL ADVANCE DISTRIBUTOR TO THE ENGINE.–Using the piston position indicator, locate the proper firing position of the No. 1 cylinder on the compression stroke. Turn the distributor shaft until the 1R mark on the rotor is alinged with the OPEN mark on the collector plate, and install the distributor on the mounting pad of the engine. Isolate the retard breaker points from the advance breaker points by disconnecting the spacers which connect the supports. Connect the timing lights across the No. 1 retard points. Secure the distributor in the position where the No. 1 retard points just open. Recheck for proper timing and for synchronization with the other distributor. Reconnect the spacers.

Ground Turnup and Checks

After starting, warm up the engine at approximately 1,200 to 1,400 rpm, until the cylinder head temperature is 125°C or more. With the throttle closed, the engine should idle at approximately 600 rpm.



AD.87

Figure 9-25.—Position of No. 2 retard points CLOSE.

IGNITION SWITCH CHECK.—The ignition switch check is accomplished with the ignition switch in all four positions while the engine is operating in the idle range.

GENERAL IGNITION CHECK.—The next step is to make a general ignition check, and for this discussion a typical magneto check based on the SP-2H follows:

1. With the propeller set at INCREASE RPM (low pitch), open the throttle to obtain static gage pressure indicated on the manifold pressure gage. Do not check the magneto at manifold pressures above static gage pressure.
2. Note the rpm with the ignition switch in the BOTH position.
3. Place the ignition switch in the LEFT position. Observe the rpm and BMEP change.
4. Return the switch to the BOTH position.
5. Allow the engine speed to stabilize before repeating steps 3 and 4 for the RIGHT position.
6. Atmospheric conditions and spark timing will influence the readings obtained.
7. On engines that are equipped with manual spark advance, a loss of up to 100 rpm and 10 brake mean effective pressure (BMEP is considered satisfactory if no engine roughness is encountered.

NOTE: The above limits are acceptable if no engine instability is encountered. Where both rpm and BMEP limits are given, the rpm limit is controlling and the BMEP additional substantiation.

8. During the magneto check, it is recommended that readings of fuel flow, rpm, and BMEP be taken so that a cross-check of performance can be made with the other engines in a multiengine aircraft. A drop of 8 to 9 BMEP is considered equivalent to a 75-rpm drop.
9. When the rpm drop exceeds 150 and/or excessive roughness is encountered, retard the throttle to idle before returning the magneto switch to BOTH.

In cases of known richer than normal carburetion, the following procedures are recommended if the limits in the general ignition check are exceeded:

1. Set manifold pressure (MAP) equal to static gage pressure with the throttle.
2. Lean mixture manually to best power setting (maximum BMEP).
3. Enrich mixture to obtain approximately 2-BMEP drop.
4. Conduct the magneto check as indicated earlier in this section. If the limits continue to be exceeded, the conditions should be investigated and corrective action should be taken.

MANUAL SPARK ADVANCE CHECK.—The manual spark advance system (if installed) may be checked with an ignition analyzer by noting the pattern shift when switching from ADVANCE to RETARD. Required spark advance is 7 degrees, plus or minus 1 degree, as measured on No. 1 and No. 2 cylinders in accordance with the analyzer manufacturer's instructions.

If the advance limits are exceeded, or if the out-of-synchronization limits, as shown on No. 1 and No. 2 cylinders, exceed 2 degrees, corrective action should be taken as soon as possible.

If it is established that a distributor is locked in RETARD (not ADVANCE), the engine may be operated until the discrepancy is corrected.

NOTE: The analyzer is not to be used for checking basic ignition timing in either ADVANCE or RETARD.

The following procedure is for ground operation only and may be used to check the advance "mechanism" without the use of an ignition analyzer:

1. Set 2,000 rpm with the throttle, and lock.
2. Lean the mixture to obtain 1,950 rpm.
3. Place the ignition switch on LEFT, select ADVANCE spark, and note the change in rpm/BMEP. Return the spark

to RETARD and the ignition switch to BOTH.

4. Repeat the procedure in step 3 with the ignition switch on RIGHT.

5. Check for a definite rise of 2 to 4 BMEP or approximately 25 rpm. If no rise occurs, the mechanism may be locked in either ADVANCE or RETARD. Until the discrepancy is corrected do not use any power above that specified for MAXIMUM CRUISE in the recommended operating schedule.

TEST EQUIPMENT

In maintaining ignition systems on aircraft reciprocating engines, you will find that certain equipment will prove invaluable. In order to use the test equipment correctly and to thoroughly understand the ignition system, it is necessary to have a working knowledge of basic electricity. The necessary test equipment for maintaining ignition systems is briefly discussed here. More detailed information may be obtained from the publications issued with the equipment.

Ohmmeter

The ohmmeter will be used on the low-tension ignition system to check for continuity, amount of resistance, or for infinity, in a circuit, or part of a circuit. The ohmmeter has its own source of power (batteries); therefore, before using, always insure that the circuit being checked is not live. This will prevent damage to the ohmmeter. One type of ohmmeter is shown in figure 9-26.

To use the ohmmeter, first turn the ohmmeter switch ON. Touch the probes together and adjust the pointer to read 0 by turning the adjusting knob. Set the selector switch to either HIGH or LOW, depending on the circuit you are going to test. The LOW setting will give you a reading in ohms. The HIGH setting will give you a reading in ohms times 1,000. For testing, put that part of the circuit to be tested between the two probes. An infinity reading indicates an open circuit. Readings between zero and infinity indicate the number of ohms resistance in that circuit. When you have finished using the ohmmeter, turn the ohmmeter switch OFF to conserve the batteries.

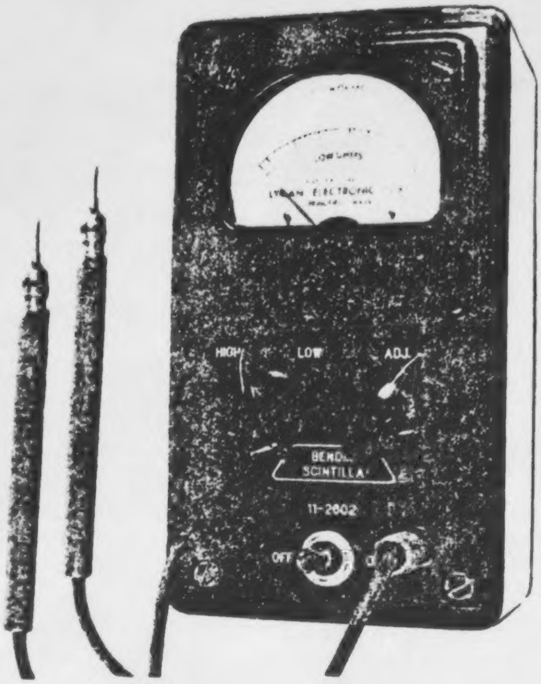


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Figure 9-26.–Ohmmeter.

High-Voltage Insulation Tester

Several types of high-voltage insulation testers are now in use. One type is shown in figure 9-27. All of the testers can be very dangerous if improperly used. The ground lead must always be connected to a good earth ground before turning on the tester. When testing a lead, the tester must be connected to that

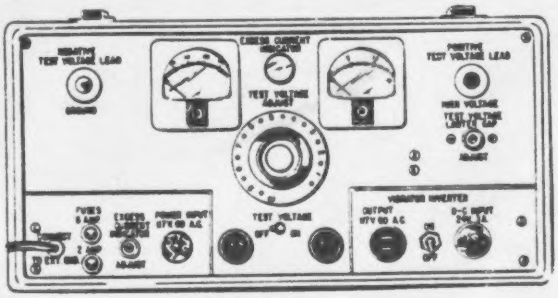

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Figure 9-27.–High-voltage insulation tester.

lead before turning on the test voltage switch. A safe procedure is to operate the equipment and secure the leads with one hand only. The positive test voltage lead is connected to the conductor of the part to be tested. The negative test voltage lead is connected to the insulation of the part to be tested. Consult the latest publication on the particular tester before using it.

Piston Position Indicator

The piston position indicator, or Time-Rite, is used to locate the desired position of the piston. One is shown in figure 9-28. Because of the variations in spark plug locations and piston dome shapes, various pivot arms and calibrated scales are available for use on different engines. Be sure to use the proper arm and scale for the engine on which you are working. Make sure the piston is on the compression stroke and not too near the top of the stroke; then screw the indicator into the front spark plug bushing of the No. 1 cylinder. Turn the cap so that the slot is vertical and the scale is on the right-hand side. (See fig. 9-29.)

Turn the engine in the normal direction of rotation so that the piston travels through the top dead center position. This will leave the slide pointer at the highest point of piston travel. (See fig. 9-30.)

Set the sliding scale so that the 0 mark on the scale is aligned with the reference mark on the slide pointer. (See fig. 9-31.)

Turn the engine back through the top center position so that the piston is near the bottom of its stroke. Without moving the scale, set the slide pointer opposite the desired timing position on the scale. (See fig. 9-32.)

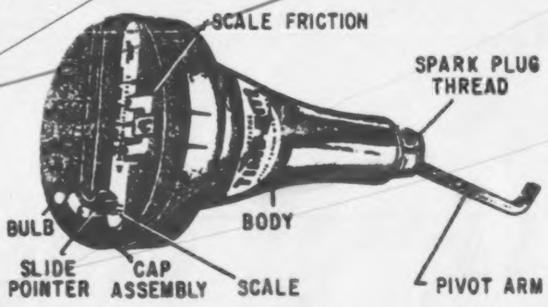

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Figure 9-28.–Piston position indicator.

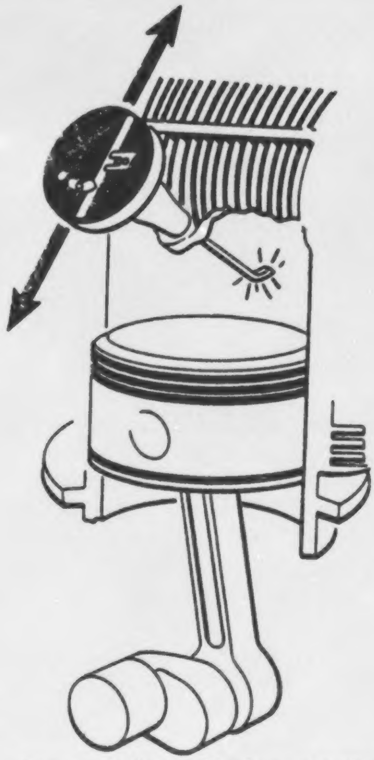

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Figure 9-29.–Indicator installed in master rod cylinder.

Now turn the engine in the normal direction of rotation until the pivot arm just touches the slide pointer, causing the bulb to light. This indicates that the piston is at the exact timing position. (See fig. 9-33.)

Timing Lights

Timing lights are used for ignition timing operations to determine the instant the breaker points open or close. There are several different types of timing lights in use. On some, the light goes OUT when the points start to OPEN. On others, the light comes ON when the points start to OPEN. Timing lights are usually equipped with 2 bulbs and 3 leads (2 red leads and 1 black ground lead). A switch conserves the batteries when the lights are not being used.

When using the lights to check the timing of the points, the primary leads to the points must

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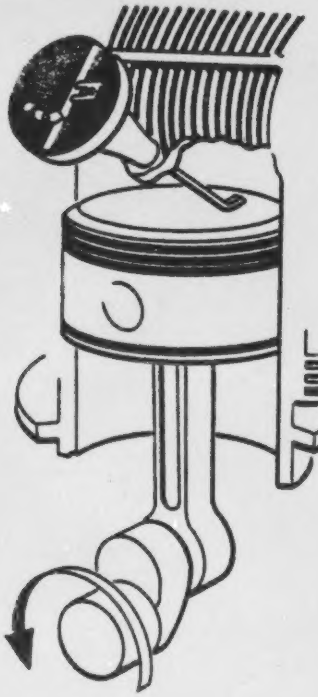

AD.91

Figure 9-30.–Bringing master rod piston to top dead center.

be disconnected. The ground lead is connected to a good ground. The red lead (or leads if two sets of points are being checked) is connected to the insulated side of the points. As the cam operating the points is rotated, the lights will indicate point OPENING and CLOSING.

USE OF DIAGRAMS, DRAWINGS, AND CHARTS

Schematic drawings of the ignition system of the engine you are maintaining are valuable aids in tracing out the wiring to each unit within the system. The mechanic should be able to draw on paper the basic schematic for the system that he maintains and be able to trace the system from the ignition switch in the cockpit to the magneto, distributors, and spark plugs. Familiarity with the units in the system and the wiring connecting them is possible through study of the schematics of the system and the actual wiring diagrams that can be found in the Service Instructions Manual for a particular engine. Additional information on the use of diagrams and drawings is included in chapter 10 of this training manual.

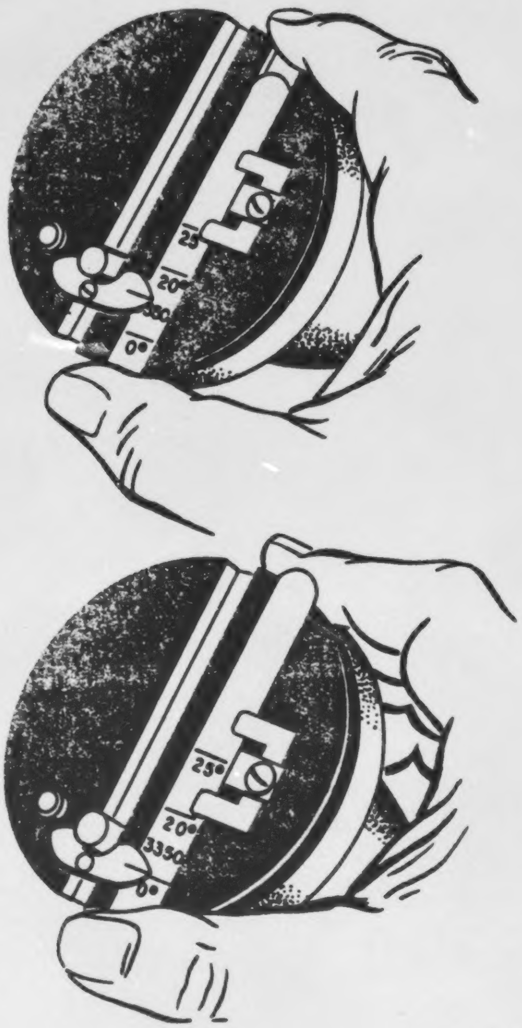

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Figure 9-31.–Setting scale.

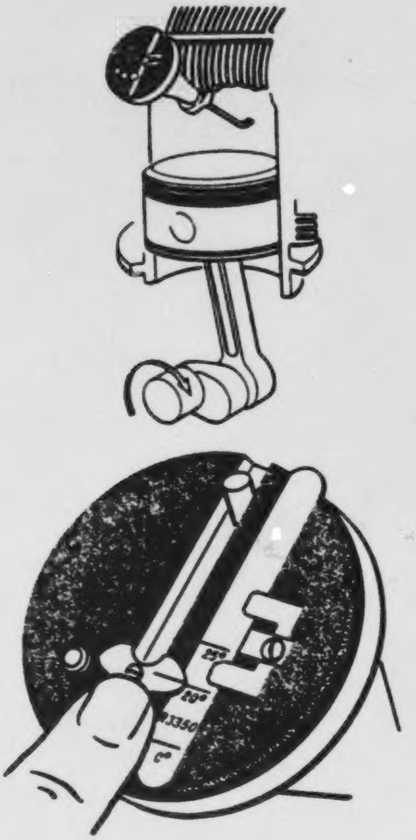
25°
20°
R3350
0°

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Figure 9-32.–Setting slide pointer at desired timing position.

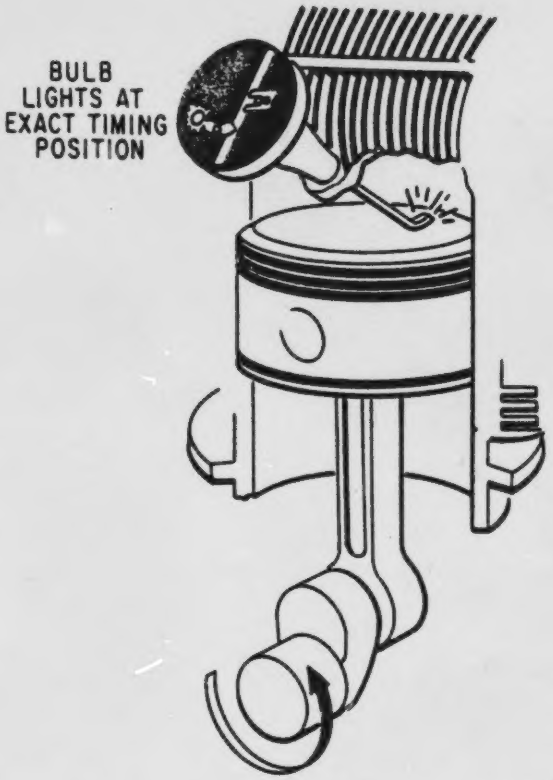
BULB
LIGHTS AT
EXACT TIMING
POSITION

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Figure 9-33.–Obtaining exact timing position.

CHAPTER 10

RECIPROCATING ENGINE ACCESSORIES

Mounted on the reciprocating engine in present day aircraft are a number of accessories that are not presented as a part of a system or systems in the other chapters of this manual. There are numerous problems which arise in maintaining an aircraft and engine that can be solved, provided the ADR has a thorough understanding of the various types of accessories and their purpose.

COOLING SYSTEM

It is essential that the operating temperature of the reciprocating engine be maintained within safe operating limits. Excessive heat will cause detonation and preignition within the cylinder head and lead to ultimate failure of some part or unit within the engine.

The reciprocating engine aircraft in flight has a continuous flow of cooling air passing over all of the power section. This cooling airflow keeps the engine temperatures within the range that assures the most efficient operation of the engine. When the aircraft is on the ground and the engine is operating, the propeller will supply air in sufficient quantity to the engine to keep it cool, provided the periods of operation of the engine are not too extended. The simplicity of the reciprocating engine cooling system makes it practically free from failures and thus simplifies maintenance problems in this area.

CYLINDER BAFFLES

The cylinder baffles are designed to force the incoming air over the cylinder cooling fins. The baffles direct the air in close around the cylinders and prevent it from forming hot pools of stagnant air while the main stream of air rushes by unused. The principle of the baffle system for cooling the cylinders is illustrated in figure 10-1.

COWLING

The cowling of the air-cooled radial engine improves the cooling efficiency and streamlines the powerplant. The cowling, in some installations, consists of a ring-shaped nose section, supported on the cylinder rocker box ears.

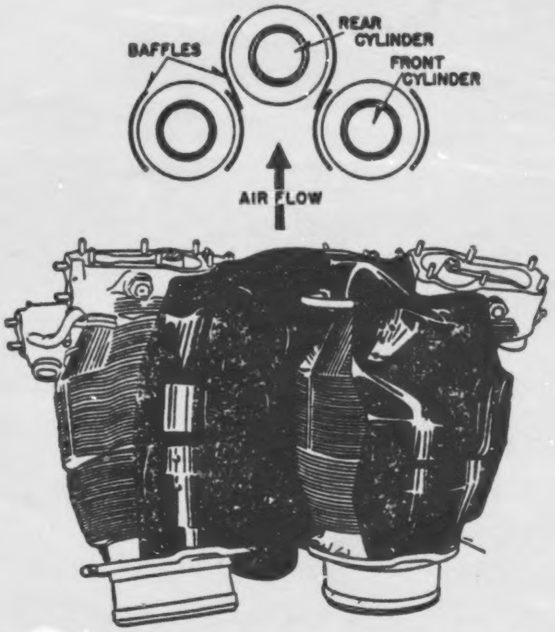

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Figure 10-1.–Baffle arrangement for twin-row engine.

Stringers extend from the cowling nosering section to the rear cowling support ring, which is supported by the rocker box ears of the rear cylinders on a twin-row engine. Removable panels are attached to the structural members of the cowling and are easily removed for maintenance and inspection of the engine. The rear cowling support ring also provides attachment points for the cowl flaps.

COWL FLAPS

The volume of the airflow around the cylinders of the engine is regulated at the rear of the engine where the air exits to the outside by opening or closing the cowl flaps. The cowl flaps are operated from the cockpit by a switch which controls a motor-operated jackscrew(s).

The cowl flaps of any engine should be in the full open position for all ground operations; and in those aircraft equipped with reversing type propellers, reversing operations should be kept to the minimum necessary for checking out the reversing system. When the propeller is reversed, there is very little, if any, cooling airflow through the engine, and engine temperatures build up quickly.

BLAST TUBES

There are a number of sizes of blast tubes that carry cooling air to sections of the engine. Individual tubes lead to each of the rear spark plugs of the engine. The tube is an integral part of the top baffle of each cylinder; ram-air pressure for cooling is directed to the top of each cylinder where it is delivered to each rear plug through its blast tube.

Several of the accessories have blast tubes connected to them for the purpose of maintaining the operating temperature of the accessory within prescribed limitations. The cooling air for these units is either picked up at the forward side of the firewall or is ducted off from the oil cooler airscoop. The accessories cooled in this manner are the generator(s) and/or the alternator(s).

TEMPERATURE MEASUREMENT

The temperature of the engine is sensed by one or more thermocouples mounted at the spark plug or by a bayonet type fitting that is inserted into a hole at the rear of the cylinder just below the spark plug.

One type of device used to measure the cylinder temperature is the spark plug gasket type thermocouple shown in figure 10-2. This type of thermocouple is a junction of two different metals. When the junction is heated, an electromotive force is developed in proportion to the temperature of the cylinder at the base of the spark plug. The strength of this electromotive force is indicated on a sensitive voltmeter calibrated in degrees C (centigrade). The instrument itself is located on the instrument panel in the engine group of instruments.

The spark plug gasket type thermocouple is installed in the place of the regular copper spark plug gasket. The thermocouple is installed in the cylinder of the engine that has proven through testing to be the hottest cylinder operating under most conditions. Of the two thermocouple wires, one is of constantan and the other of copper. Each wire is designed so that it may be properly installed on the cylinder head temperature gage in the cockpit.

ELECTRICAL SYSTEM

It is necessary for the ADR to have a knowledge of basic electricity in order to better understand the electrical functions of some of the engine accessories.

Primarily there are two sources of electrical energy in an aircraft other than the magneto—the generator, in which mechanical energy delivered by the engine through the gear

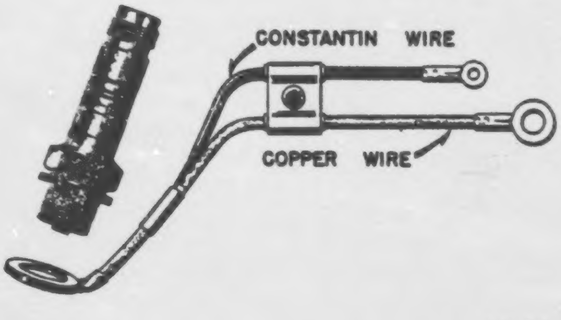

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Figure 10-2.—Spark plug gasket type thermocouple.

train is converted into electrical energy; and the battery, in which chemical energy is converted into electrical energy.

An understanding of the fundamentals of electricity is essential in becoming a proficient reciprocating engine mechanic. An excellent presentation on these fundamentals is presented in Basic Electricity, NavPers 10086-B. Men seeking advancement to ADR3 should obtain a copy of this basic training manual and study it, particularly the first eight chapters. An understanding of the fundamentals of electricity is assumed in the section following, which is devoted to coverage on aircraft generators, batteries, alternators, and starters. If you do not already have an understanding of the fundamentals of electricity, study NavPers 10086-B first.

GENERATORS

A generator is a device which converts mechanical energy into electrical energy (EMF). Electrical power required for the operation of the various electrically operated aircraft units is supplied by a generator mounted on the rear (accessory) section of the engine. When the demand for electrical power exceeds the output of the engine-driven generator, an auxiliary electrical powerplant may be installed to supply the additional requirements of the multitude of units found on large aircraft.

Since the maintenance of an aircraft generator is generally considered to be one of the duties of Aviation Electrician's Mates, no attempt will be made here to describe the minute details of operation. However, it is highly desirable that you, as an ADR, have some general information regarding this piece of equipment because it is so vital to the operation of the aircraft and is closely associated with the engine for which you are responsible.

The type of generator used on any particular aircraft depends upon the amount of power required and the nature of current needed to operate the individual units. Radio communication equipment generally requires alternating current for its operation. Other units require direct current. Therefore, generators may be constructed to supply either alternating current or direct current, or both.

The engine-driven generator is usually a direct-current device, since one of the prime requirements of a generator is the furnishing of a source of direct current for charging the aircraft battery. This type of generator is shown in figure 10-3.

It is impossible to charge a storage battery with alternating current without first converting (rectifying) the alternating current into direct current. This necessitates the use of additional heavy equipment. Some generators are equipped with two sets of windings, designed to supply both alternating and direct current.

Since it is imperative that the weight of a generator be kept to a minimum, it becomes necessary to increase the output of the generator without a corresponding increase in weight. This has been accomplished by stepping up armature speeds until they approach the maximum safe limits.

One factor which has limited the power output of a generator has been the production of destructive heat as a byproduct. Cotton, silk, or enamel insulation used on generator wiring will break down under extreme heat, making it necessary to keep generator temperatures below the critical heat limit. This is accomplished by the use of built-in fans and the addition of blast tubes which carry cooling air to the generator from the slipstream. Some generators use spun glass insulation which does not break down under extreme temperature. Such improvements have made it possible for the modern generator to more than double the output of the older aircraft generators without any corresponding increase in weight.

Under normal flight conditions, current consumption is not great. On the other hand, large quantities of current are needed for starting, for landing lights, and for the operation of landing gear and flaps through short periods of time on aircraft using electrically operated units. Consequently, the generator must be capable of very quickly recharging a practically exhausted battery.

The generator on an aircraft engine is operated by a shaft driven by the main accessory drive shaft of the engine through a gear

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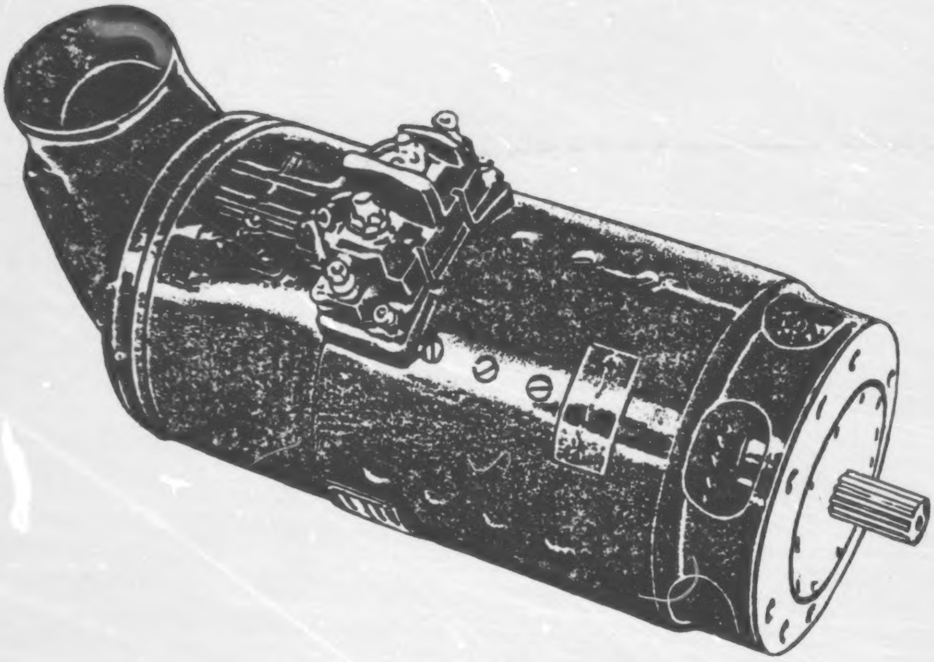

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Figure 10-3.–D-c generator.

arrangement. A separate regulating mechanism (voltage regulator) takes care of the intermittent load requirements while at the same time preventing overcharge of the battery.

ALTERNATORS

The maintenance of the alternator or a-c (alternating current) generator is one of the duties of the Aviation Electrician's Mate, as is the d-c generator, and no attempt is made here to describe the many details of its operation. It is desirable that you as an ADR have some general knowledge concerning this piece of equipment, as it is vital to the operation of the electrical power systems of our modern day aircraft.

Since the various devices that operate on a-c require a certain voltage and frequency, the speed of the generator should be constant. The engine speed varies considerably from the idle range all the way through to full power output; thus, the a-c generator is driven by the engine through a constant speed drive unit installed between the engine and the generator.

The constant speed drive unit is a hydraulic transmission which may be either electrically or mechanically controlled. It is designed to deliver a constant rpm output, provided the input from the engine remains within a minimum and a maximum rpm. In operation, the constant speed drive unit is similar to the overdrive of an automobile engine. The constant speed drive unit enables the alternator to produce the same frequency at speeds slightly above idle rpm as it would at maximum power or at cruising speeds.

The a-c generator itself is rated according to kilovolt-amperes (kva), power factor, phases, voltage, and frequency. One generator, for example, may be rated at 40 kva, 208 volts, 400 cycles, three phase, at a 75 percent power factor. The kilovolt-ampere indicate the apparent power. This is the kilovolt-ampere output, or the relationship between the current and voltage at which the generator is intended to operate.

The power factor is the expression of the ratio between the apparent power (volt-amperes) and the true or effective power (watts). The number of phases is the number of independent

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voltages generated. Three-phase generators generate three voltages 120 electrical degrees apart. Both single- and three-phase generators are commonly used.

BATTERIES

The battery is the other source of an electromotive force in the aircraft. The function of the aircraft storage battery is to provide a reserve source of electrical power for operating the electrical systems of the aircraft. The battery also functions in such a manner that it eliminates the commutator ripple which is produced by the d-c generator. During normal aircraft operations, the generator supplies the primary source of electrical energy and maintains the battery in a charged state. The battery supplies power to the aircraft only when the speed of the engine or generator drive system becomes so slow that the generator's output voltage falls below the battery voltage.

The battery is the emergency power source for the aircraft. For this reason, extreme care must be taken to see that every precaution is made to maintain the battery in perfect condition. Therefore, the battery should never be used for starting engines or servicing equipment if another source of power is available. Such unnecessary usage tends to shorten the life of the battery and keeps the battery in poor condition to meet emergency operating requirements. During the periods when the engine is idling or being started, the electrical load should be kept to a minimum. The service life of the battery depends a great deal upon the frequency and quality of care it is given. Batteries that are abused or that receive careless treatment and servicing generally have their service life ended prematurely.

STARTER

An aircraft engine starter is a mechanism for developing a considerable amount of mechanical energy that can be applied to the engine to cause it to rotate. The starter must develop sufficient power and be dependable, light in weight, and simple to operate and maintain.

The type of starter used for cranking reciprocating engines is the direct cranking starter. Figure 10-4 shows a typical direct cranking electric starter for reciprocating engines.

This starter contains a series-wound electric motor, speed reduction gears, an overload clutch, and an automatic engagement jaw. The torque developed in the motor is transmitted to the jaw through a gear reduction system. Because of the high-speed characteristics of the motor and the lightweight structural design, the overall weight is reduced to a minimum and, at the same time, maximum cranking torque is maintained. The high speed of the motor is reduced by gear reduction between the motor armature and the low-speed starter jaw.

A torque limiting clutch incorporated in the housing prevents damage either to the starter or the engine when the moving starter jaw is engaged with the stationary engine jaw. The clutch plates will slip when the torque exceeds the clutch setting of the starter. As the torque decreases to a value less than the clutch setting, the clutch plates will again be held stationary and allow the jaw to rotate at the speed of the motor through the reduction gearing.

The starter jaw is automatically engaged with the engine jaw by means of a spiral spline actuating device. When the engine starts, the sloping ramps of the jaw teeth cause the disengagement of the starter and engine jaws. Oil seals are provided to prevent leakage of engine oil into the starter.

Starting motors are of the intermittent-duty type. They MUST be allowed to cool between starting intervals in order to prevent overheating

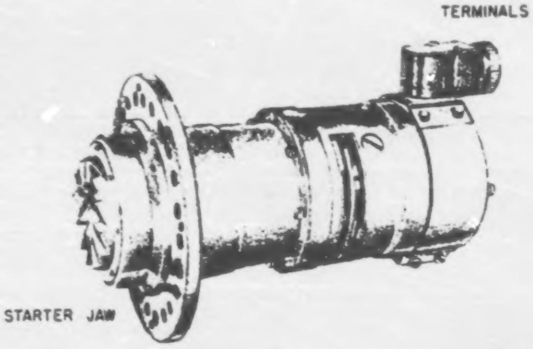

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Figure 10-4.–Typical direct cranking electric starter.

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and possible damage. Consult the applicable manual for specific information on the particular starter for the aircraft with which you are working.

EXHAUST SYSTEM

The purpose of the exhaust system is to conduct the exhaust gases from the engine to the outside atmosphere with a minimum resistance of exhaust back pressure. Some naval aircraft are equipped with short exhaust stacks, used singly for each cylinder, or they are designed to accommodate two or three cylinders. These stacks conduct the exhaust gases through spaced openings in the cowling around the rear of the engine power section. On other aircraft, the short individual stacks join to a collector ring which, in turn, expels the hot gases through one large tailpipe.

EXHAUST STACKS

The R-3350 engine installed in multiengine aircraft has a power recovery system composed of three blowdown turbines (power recovery turbines) mounted 120 degrees apart on the supercharger front housing. The exhaust gases from six cylinders are expelled through a power recovery turbine. These gases are directed to the power recovery turbine via various types of exhaust stacks. Figure 10-5 shows the configuration of the long L, short L, T, Y, and F type stacks.

POWER RECOVERY TURBINES

The R-3350-32W and -34 engine models incorporate three interchangeable exhaust power recovery turbines (PRT's). Figure 10-6 is a cutaway view of the power recovery turbine used in compounding these engines. Each of these turbines is clamped to adapters that are mounted on the supercharger front housing and spaced 120 degrees apart.

Operation

The PRT's utilize the energy of the exhaust gases coming from the cylinders and transmit this energy back to the engine crankshaft. They will add approximately 150 horsepower per turbine for a total of 450 horsepower to the horsepower output of the engine at maximum allowable power. Each PRT utilizes the exhaust gases from six cylinders—three front and three rear. (See fig. 10-7.)

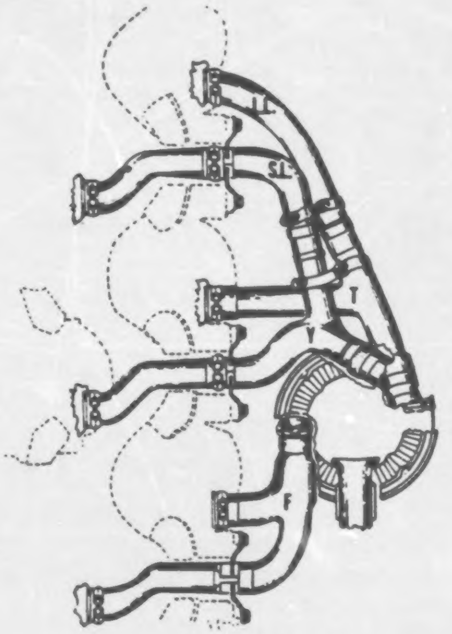

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Figure 10-5.—Exhaust stack configuration.

The gases enter the turbine at the nozzle assembly and cause the turbine wheel to spin at high speed. A hollow shaft, splined to the turbine wheel, passes through a support clamped to the adapter on the supercharger front housing. A vibration damper assembly, consisting of spring-loaded plates and discs, assists in dampening the lateral vibration and the whip of the turbine shaft. A coupling, splined at each end, connects the turbine shaft to a bevel drive gear in the supercharger front housing. The drive gear meshes with a larger bevel gear, connected by a drive shaft to the fluid coupling impeller. The fluid coupling rear half (runner) is connected by a splined shaft to a pinion, which meshes with the PRT crankshaft drive gear coupled to the engine crankshaft. Figure 10-8 illustrates the transmission of the exhaust gas energy to the turbine wheel and back to the crankshaft.

To prevent damaging effects from the high temperatures of exhaust gases, cooling air is drawn from a duct between the cylinders and conducted to the turbine assembly. A tube and duct assembly delivers the air between the nozzle support and the cooling air shield. An impeller is provided to force the cool air through the assembly and to discharge it, together with the exhaust gases, from the outer shield outlet. Cooling air is sealed under the turbine wheel by the labyrinth seal facing the underside of the impeller. The seal prevents the mixing of the exhaust gases and cooling air until both are discharged from the outer shield. Oil from the turbine drive shaft is kept from entering the stream of cooling air by the bellows-loaded seal, which fits tightly in the turbine shaft oil seal support.

Oil under reduced pressure, is brought from the pressure control valve located in the supercharger front housing by way of internal passages to the PRT fluid coupling support. From the fluid coupling support, oil flows through passages in the supercharger front housing to an annulus in the turbine coupling gear shaft bushing and through passages in the support to the fluid drive shaft. From the coupling gear shaft bushing, a passage in the front supercharger housing carries oil to the fluid drive shaft. The oil entering from either end of the shaft lubricates the bushing on the shaft and passes through a set of holes into the fluid coupling, supplying the necessary pressure for operation.

When the engine is being started, before oil pressure is built up in the fluid coupling, the impeller will not drive the runner. When sufficient oil pressure is built up in the coupling after starting, the runner will then follow the impeller with a certain amount of slippage which will act to absorb any undesirable amount of vibrational conflict between the crankshaft and the PRT unit. As engine rpm increases, the amount of slippage between the runner and the impeller decreases. The fluid coupling is a vortex type, giving a swirling action to the oil to prevent sludge formation which might freeze the halves of the coupling together and nullify their effect.

Maintenance

The maintenance of the exhaust system consists of a visual inspection of all sections of the system from the cylinder exhaust ports to the final exit of the exhaust gases to the atmosphere. The complete system is to be checked for any evidence of gas leakage at the joints, cracks in the piping, looseness of clamps, and the security of all units in the system. NOTE: Clamps should be tightened to specific torque listed in the aircraft maintenance instructions manual. Do not overtighten, as heat expansion may lead to failure. When replacing any units in the exhaust system, care should be maintained to use the proper type nuts, bolts, and cotter pins or safety wire. Do not use aluminum nuts, bolts, washers, or material that is made of any soft metal in any part of the exhaust system.

CAUTION: Lead deposits in exhaust system are poisonous; wash hands thoroughly before eating, drinking or smoking. Use caution in removing exhaust components to avoid inhalation of deposits.

HYDRAULIC SYSTEM

A complete aircraft hydraulic system is made up of two or more power systems and a number of actuating systems, the number of actuating systems depending upon the design of the aircraft. Current specifications require at least two power systems.

A power system is generally considered to include a fluid reservoir, pump, and all the other components leading up to, but not including, the selector valves. The selector valves direct the flow of fluid to the various actuating units, and each selector valve is considered to be part of its related actuating system.

The portion of the hydraulic system with which the ADR is primarily concerned is that section of the system forward of the firewall, consisting of the supply and the return lines and the hydraulic pump; however, if the ADR is a plane captain, he should be familiar with the complete system.

A brief discussion of hydraulic principles, followed by a brief description of pumps, is presented in the following paragraphs. For more detailed information on hydraulic principles, reference should be made to Fluid Power, NavPers 16193-A. For the plane captain who is interested in more detailed information on the complete aircraft hydraulic system, a good source is Aviation Structural Mechanic H 3 & 2, NavPers 10310-A.

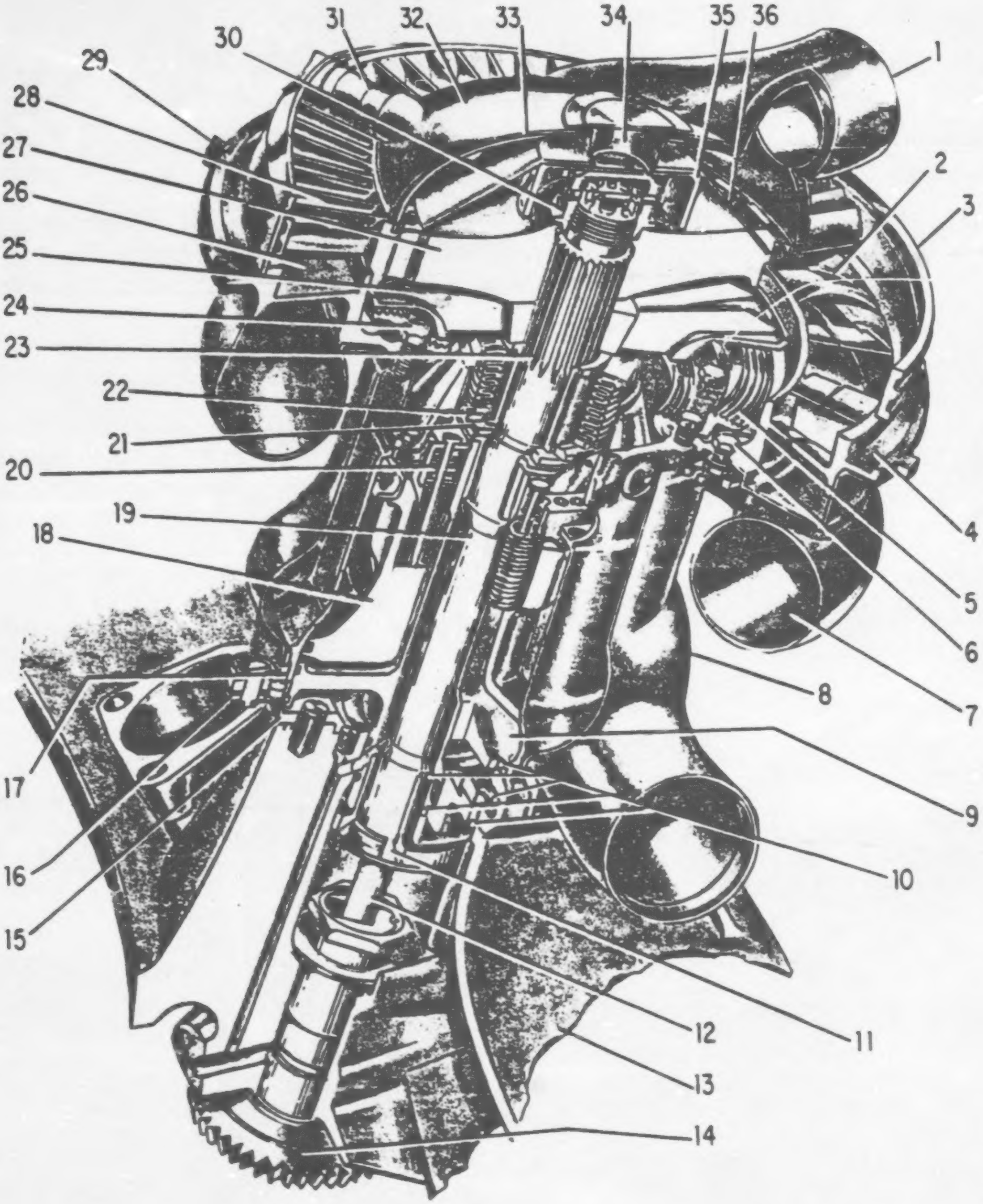
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Figure 10-6.–Power recovery turbine (cutaway view).

Nomenclature for figure 10-6.

1. Cooling shield assembly.
2. Nozzle solid vane.
3. Cooling shield flange ring.
4. Nozzle flange.
5. Labyrinth seal.
6. Inlet pipe retaining bolts, nuts, and washers.
7. Inlet pipe.
8. Cooling air duct.
9. Shaft support.
10. Shaft support and adapter packing rings.
11. Lower thrust washer.
12. Gear coupling.
13. Supercharger front housing.
14. Shaft gear.
15. Mounting pad.
16. Clamp.
17. Nozzle support and adapter locating pins.
18. Shield and seal assembly.
19. Shaft.
20. Vibration damper.
21. Upper thrust washer.
22. Shaft oil seal ring.
23. Cooling air impeller spacer.
24. Nozzle assembly to nozzle support cap screws.
25. Cooling air impeller.
26. Nozzle split vane.
27. Turbine wheel.
28. Turbine wheel buckets.
29. Flight hood locating lug.
30. Wheel retaining nut.
31. Cooling shield support.
32. Outer shield.
33. Intermediate shield.
34. Pylon support.
35. Cooling shield inner flange.
36. Inner shield.

FUNDAMENTALS OF HYDRAULICS

The word hydraulics is based on the Greek word for water, and originally meant the study of the physical behavior of water at rest and in motion. Today, the meaning has been expanded to include the physical behavior of all liquids, including hydraulic fluid.

Pascal's Law

Hydraulics is based on the idea that a confined liquid will pass on any pressure applied to it until the pressure at any given point is equalized. This principle was first stated in the year 1693 by the French scientist, Pascal, and is commonly known as Pascal's law. Pascal's law states: Pressure applied to an enclosed or confined fluid is transmitted equally in all directions without loss and acts with equal force on equal surfaces.

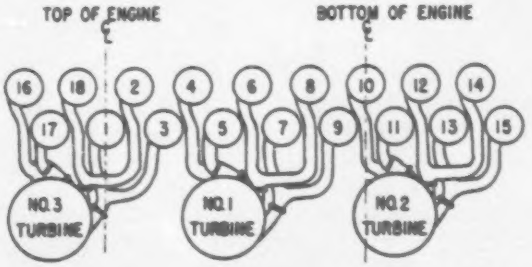

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Figure 10-7.–Exhaust system arrangement.

Although Pascal's principle applies to both liquids and gases, a liquid is used in hydraulic systems because liquids are practically incompressible. Under terrific pressure, the volume of a liquid can be decreased somewhat, but the decrease is so slight that it is of no consequence in hydraulic applications. Because of this fact, hydraulically operated mechanisms are almost instantaneous in action.

Force and Pressure

In order to understand how Pascal's principle is applied to hydraulics, you must distinguish carefully between the terms FORCE and PRESSURE. Force may be defined as a push or pull. It is the push or pull exerted against the TOTAL AREA of a particular surface and is expressed in pounds. Pressure is the amount of push or pull on a UNIT AREA of the surface acted upon. In hydraulics, the unit of area is the SQUARE INCH; therefore, pressure is expressed in pounds per square inch, abbreviated psi.

It is important to bear in mind that when referring to pressure, we deal with the amount of force acting upon one square inch of area.

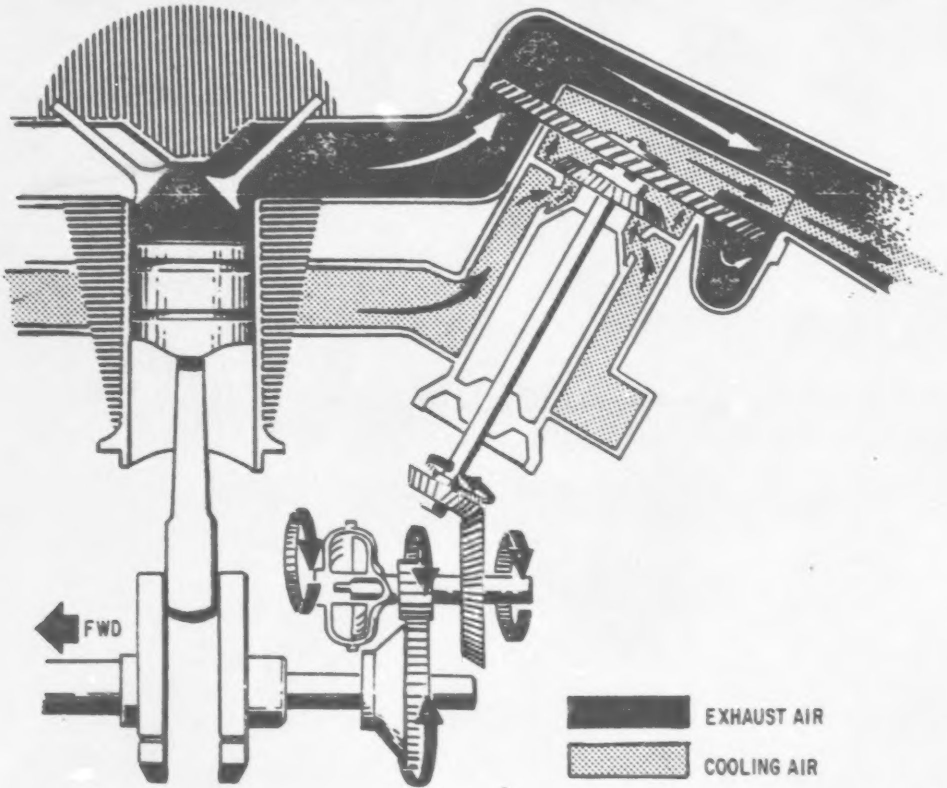

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Figure 10-8.–Transmission of exhaust energy back to the crankshaft.

Computing Force, Pressure, and Area

A simplified form of writing a long statement or sentence with the use of symbols is known as a formula. For example, rather than say "length times width equals area," we simply write:

$$L \times W = A$$

When dealing with pressure, force, or area, a similar method of shorthand is used.

TO FIND FORCE.–It is known that force equals pressure times area. Substituting F for force, P for pressure, and A for area, we have:

$$F = P \times A$$

TO FIND PRESSURE.–It has been found that pressure equals force divided by area. For the sake of brevity and simplicity, let us condense this statement into symbols:

$$P = \frac{F}{A}$$

TO FIND AREA.–Since area equals force divided by pressure, we merely state:

$$A = \frac{F}{P}$$

Figure 10-9 illustrates a device for recalling the above mentioned formulas. Any letter in the triangle may be expressed as the product or quotient of the other two, depending upon its position in the triangle.

For example, to determine the formula for finding area, consider the letter A as being set off to itself, followed by an equals sign. Now

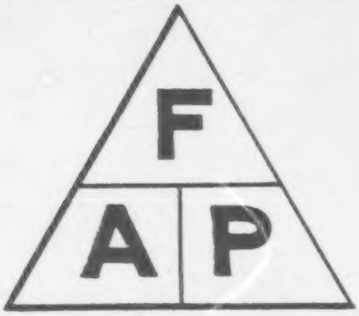

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Figure 10-9.–Device for determinine force, area, and pressure formulas.

look at the other two letters. The letter F is above the letter P; therefore,

$$A = \frac{F}{P}$$

In order to determine the formula for finding pressure, consider the letter P as being set off by itself and look at the other two letters. The letter F is above the letter A; therefore,

$$P = \frac{F}{A}$$

Likewise, to determine the formula for finding force, consider the letter F as being set off to itself. The letters P and A are side by side, therefore,

$$F = P \times A$$

Transmitting of Pressure by Liquids

Figure 10-10 illustrates how a small force may be multiplied into a large force through the transmission of pressure by liquids. A small cylinder and a large cylinder are connected with tubing, and the entire assembly is filled with a liquid.

Each cylinder contains a tight fitting piston. Piston A, in the smaller cylinder, is 2 square inches in area; piston B, in the larger cylinder, is 20 square inches in area.

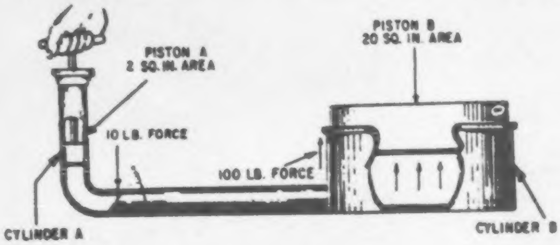

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Figure 10-10.–Transmission of pressure by liquids.

If 10 pounds of force is exerted on piston A, and its area is 2 square inches, then there are 5 pounds of pressure being exerted on each square inch of undersurface.

$$(P = \frac{F}{A}, \text{ or } P = \frac{10}{2} = 5 \text{ psi})$$

According to Pascal's law, this 5 psi pressure is transmitted in all directions without loss, and acts with equal force on equal surfaces. Therefore, the pressure being exerted against the undersurface of piston B is 5 psi. If the area of piston B is 20 square inches, the total force being exerted against piston B is equal to 20 times 5, or 100 pounds. Thus,

$$(F = P \times A)$$

In the above example, the total force against the large piston is 10 times as great as that against the small piston. If piston A were made smaller, the pressure created in the liquid would be greater, and the total force acting upon piston B would be increased.

For example, if the area of piston A was 1 square inch, the pressure created would be 10 psi, and the total force exerted against piston B would be 20 times 10, or 200 pounds.

From these basic facts it can be seen that there is practically no limit to the total force that can be obtained through the use of liquids under pressure. This is the principle used in the common hydraulic jack and the hydraulic lift, and is the principle according to which all the mechanisms in an aircraft hydraulic system are actuated.

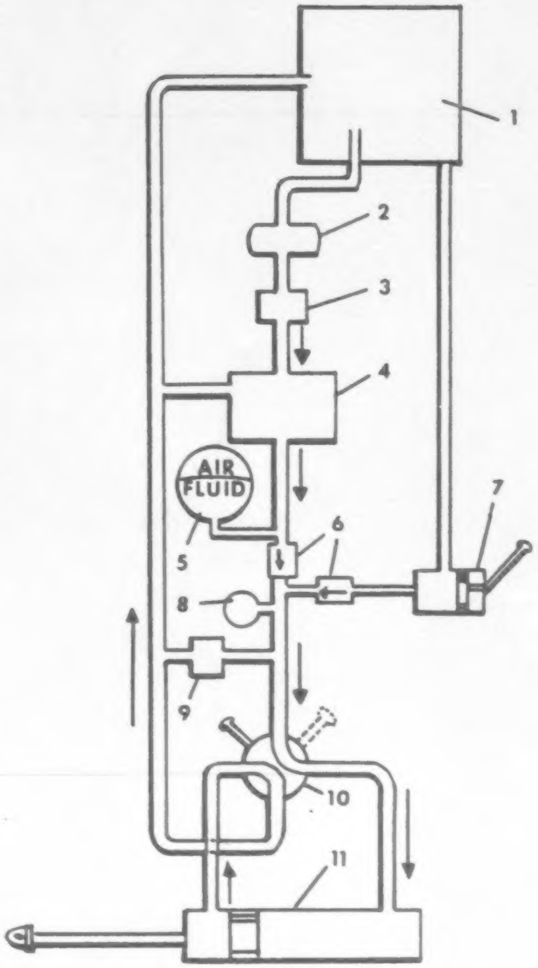
BASIC SYSTEM OPERATION

Basically, any hydraulic system must contain the following units:

1. A reservoir to hold a supply of hydraulic fluid.
2. A pump to provide a flow of fluid.
3. Tubing to transmit the fluid.
4. A selector valve to direct the flow of fluid.
5. An actuating unit to convert the fluid pressure into useful work. A simple basic system using these essentials is shown in figure 10-11.

The flow of hydraulic fluid can be traced readily from the reservoir through the pump to the selector valve. With the selector valve in the position shown, the flow of fluid created by the pump flows through the valve to the right-hand end of the actuating cylinder. Fluid pressure then forces the piston to the left and at the same time the fluid which is on the left-hand side of the piston is forced out, up through the selector valve, and back to the reservoir through the return line.

When the selector valve is moved to the position indicated by the dotted lines, the fluid from the pump then flows to the left-hand end of the actuating cylinder, thus reversing the process. Movement of the piston can be stopped at any time simply by moving the selector valve to neutral. In this position, all four ports are closed and pressure is trapped in both working lines. This basic system is one from which any hydraulic system can be derived. Additions may be made to it for the purpose of providing additional sources of power, operating additional cylinders, making operation more automatic, or increasing the reliability; but these additions are all made on the framework of the basic hydraulic system diagrammed in figure 10-11.



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1. Reservoir.
2. Power pump.
3. Filter.
4. Pressure regulator.
5. Accumulator.
6. Check valves.
7. Hand pump.
8. Pressure gage.
9. Relief valve.
10. Selector valve.
11. Actuating unit.

Figure 10-11.—Basic hydraulic system.

HYDRAULIC PUMPS

All aircraft hydraulic power systems have one or more power-driven pumps and may have a hand pump as an additional source of power. Power-driven pumps are the primary source of power and may be either engine driven or electric motor driven. As a general rule, motor-driven hydraulic pumps are installed for emergency use, or for use when the engine-driven pump is inoperative. Hand pumps are generally installed for testing purposes and for use in emergencies. The pump with which we are concerned in this chapter is the engine-driven pump.

The engine-driven pump is mounted on the accessory section of the engine or the rear cover

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plate. Pumps are classified according to the type of pumping action utilized, and may be either the gear type or the piston type. Pumps may be further classified according to whether they are designed for constant displacement or variable displacement.

A constant displacement pump is one that displaces or delivers a constant fluid output for any rotational speed. For example, a pump might be designed to deliver 3 gallons of fluid per minute at a speed of 2,800 revolutions per minute. As long as it runs at that speed, it will continue to deliver at that rate, regardless of the pressure in the system. For this reason, when the constant displacement pump is used in a system, a pressure regulator or unloading valve must also be incorporated in the system.

A variable displacement pump has a fluid output that varies to meet the demands of the system. For example, a pump might be designed to maintain a system pressure at 3,000 psi by varying its fluid output from 0 to 7 gallons per minute. When this type of pump is used, no pressure regulator or unloading valve is needed, since no pumping action takes place except when pressure is required in the system.

LOCATION OF LEAKS

External leaks in a hydraulic system where fluid is escaping from a cylinder, valve, or fitting may generally be found by a visual check. A leak in the system usually causes an accumulation of hydraulic fluid. It may happen that the actual leak is not located directly above the accumulation of fluid, since the hydraulic fluid tends to follow the structure or tubing to a lower point before dropping off. When leaks are located or noticed, notify the hydraulic shop immediately.

Internal leaks are caused by fluid under pressure slipping past an unseated valve or worn packing ring into the return line to the reservoir. The indications of internal leakage are sluggish operation of an actuating system or a dropoff in system pressure. A drop in gage pressure or an indication of insufficient pressure on the gage may be caused by an internal leak. When internal leakage is suspected or known to be in the hydraulic system, the symptoms should be noted, an effort made to locate the leak, and the hydraulic shop notified so that remedial action may be taken to repair or replace the unit or units suspected of causing the difficulty.

VACUUM PUMP

Another major accessory mounted on a drive pad on the accessory section of the engine is the vacuum pump. This pump unit is of the rotary, four vane, positive displacement type, suitable for operation in either direction of rotation. The unit consists primarily of a housing containing a sleeve in which an offset rotor with four moving blades is driven by a splined shaft which is coupled to the accessory gear train of the engine.

The pump is designed to provide suction for the operation of flight instruments and pressure for operating de-icing equipment of the inflated-tube variety.

USE OF SCHEMATIC DIAGRAMS, DRAWINGS, AND CHARTS

Troubleshooting of the various engine accessories is the process of locating a malfunctioning component or mechanism. In order to troubleshoot intelligently, the ADR must be familiar with the system at hand. He must know the function of each component and have a mental picture of the location of each component in relation to other components within the system. This can best be achieved by studying diagrams or drawings of the system.

Each manufacturer of engines and aircraft is required to furnish diagrams and drawings of the various systems, subsystems, and major components. These diagrams and drawings may be found in the various maintenance manuals supplied by the manufacturer.

DIAGRAMS

The most commonly used diagram is the shcematic. Schematic diagrams are used to illustrate the various electrical circuits, fuel systems, lubrication systems, etc. The components of electrical circuits are usually represented by electrical symbols, the most common of which are shown in figure 10-12.

A schematic diagram of a starter vibrator circuit is shown in chapter 9, figure 9-13. In chapter 8, figure 8-1 is an example of an oil system schematic.

In figure 8-1, the various lines (supply, hot return, cold return, dilution, vent, etc.) are

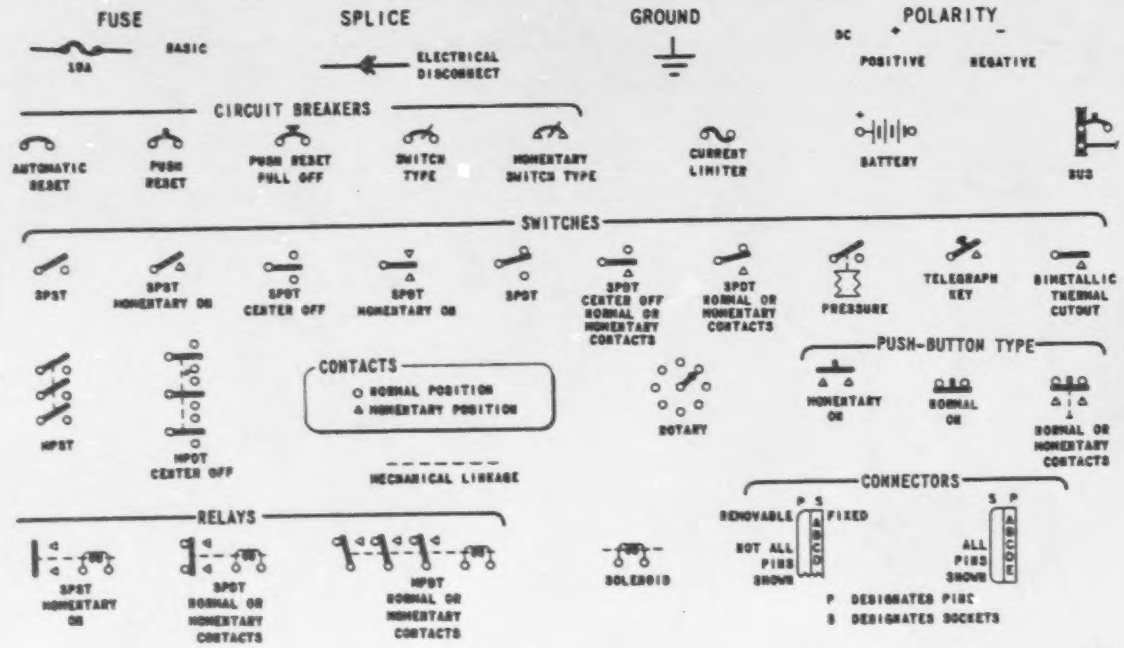
FUSE
BASIC
10A
SPLICE
ELECTRICAL DISCONNECT
GROUND
POLARITY
DC
+
-
POSITIVE
NEGATIVE
CIRCUIT BREAKERS
AUTOMATIC RESET
PUSH RESET
PUSH RESET PULL OFF
SWITCH TYPE
MOMENTARY SWITCH TYPE
CURRENT LIMITER
+
BATTERY
BUS
SWITCHES
SPST
SPST MOMENTARY ON
SPDT CENTER OFF
SPDT MOMENTARY ON
SPDT
SPDT CENTER OFF NORMAL OR MOMENTARY CONTACTS
SPDT NORMAL OR MOMENTARY CONTACTS
PRESSURE
TELEGRAPH KEY
BIMETALLIC THERMAL CUTOUT
MPST
MPDT CENTER OFF
CONTACTS
○ NORMAL POSITION
△ MOMENTARY POSITION
MECHANICAL LINKAGE
ROTARY
PUSH-BUTTON TYPE
MOMENTARY ON
NORMAL ON
NORMAL OR MOMENTARY CONTACTS
RELAYS
SPST MOMENTARY ON
SPDT NORMAL OR MOMENTARY CONTACTS
MPDT NORMAL OR MOMENTARY CONTACTS
SOLENOID
CONNECTORS
P S
REMOVABLE
FIXED
NOT ALL PINS SHOWN
A B C D
S P
ALL PINS SHOWN
A B C D E
P DESIGNATES PINS
S DESIGNATES SOCKETS

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Figure 10-12.–Electrical symbols.

shown in different colors for easy identification of each line. Each component is illustrated and identified by name, and arrows indicate the direction of flow through each line.

Block diagrams are also used to illustrate the systems of aircraft and engines. In the block diagram, each component is represented by a block. Near each block is usually written the name of the component represented by that block.

Block diagrams, like schematic diagrams, are useful in showing the relationship of the components with each other within the system. They may also show the sequence in which they operate.

DRAWINGS

Drawings are commonly used to show construction details and operating principles of various components and mechanisms. Some of the most commonly used types of drawings are the pictorial, exploded, cutaway, and orthographic.

In chapter 7 are some good examples of several types of drawings. Figure 7-1 is a cutaway drawing of a fuel strainer, with arrows showing the flow of fuel through the filter element.

Exploded views are often used to show how complex components are put together. This type of drawing is useful in disassembling and reassembling components. Figure 12-11 is an example of an exploded view, showing the principal parts of a propeller dome assembly.

Orthographic drawings are used to show the actual dimensions and construction details of parts, components, and other objects, and are primarily for use by the man who is to manufacture the object. Usually two or more views of the object are shown in orthographic drawings, and all dimensions necessary for manufacturing the object are given on the drawing. The ADR is seldom confronted with this type of drawing; however, detailed instructions on reading orthographics, as well as all other types of drawings, are contained in the Rate Training Manual, Blueprint Reading and Sketching, NavPers 10077-B.

CHAPTER 11

RECIPROCATING ENGINE REPAIR

ENGINE PERFORMANCE

The effects of RPM, MAP, and BMEP interrelationships on engines and engine performance are very important to the Aviation Machinist's Mate R.

The first concern in the discussion of engine performance is to designate the power ranges of the engine. The power delivered by an aircraft engine usually falls into three categories. Power output up to about 25 percent of rated power is considered to constitute the IDLE range. Power output from 25 percent to about 60 percent of rated power constitutes the CRUISE range. The power output of 60 percent of rated power, and above, make up the HIGH POWER range.

In the cruise range, an air-fuel mixture ratio can be used that gives most miles per gallon. This air-fuel mixture is called the BEST ECONOMY MIXTURE and is approximately 15 to 1; however, as the mixture enters the cylinder, it might easily be 18 or 20 to 1.

In the first third of the high power range a richer air-fuel mixture is used (60% to 75%), and this is called the BEST POWER MIXTURE. Above 75 percent of rated power, a still richer mixture is used, called the FULL RICH MIXTURE.

The additional fuel used to enrich the best power mixture to obtain full rich is not added primarily to provide an additional source of power. It acts as a coolant. The best power air-fuel ratio is capable of developing the required power when carried up into the upper part of the high power range. Enriching the mixture beyond the value for best power has a tendency to cut down power output, but the heat generated in the upper part of the high power range is such that it cannot be dissipated by the normal cooling method. This excess heat will tend to cause detonation of the best power mixture. Enriching the best power mixture provides extra fuel that absorbs much of the cylinder heat and carries it out through the exhaust stacks.

The amount of power that an engne will put out is usually determined by the amount of air-fuel mixture that can be consumed by the engine per unit of time. It is evident that up to certain limits an engine with more cylinders (or an engine with larger cylinders) will give greater power. Size and shape of the combustion chamber is also another built-in factor that helps determine the amount of power developed.

Aside from the built-in (or construction) factors, there are several main factors which are variable and subject to control that directly affect engine power output. These include revolutions per minute of the engine (RPM) and manifold pressure (MAP), which is another term for the amount of air-fuel mixture consumed per minute.

MAP

When considering an engine with a given air-fuel mixture, the power output will be a function of MAP and engine RPM. These two variables are hooked together in such a manner that decrease in RPM will necessitate an increase in MAP to maintain any specific power output; and conversely, an increase in engine RPM will call for a decrease in MAP if there is to be no change in engine power output.

Efficient power control requires operation of the engines at maximum allowable combustion pressure in the cylinders. MAP is directly related to this pressure. Therefore, for all power outputs an engine RPM must be specified so that the related MAP will not cause allowable cylinder pressures to be exceeded. Each engine is actually rated according to allowable RPM for various power outputs so that maximum efficiency of operation will be present at all times without exceeding the limits of cylinder pressures.

RPM

If it is assumed that power depends on the amount of air-fuel charge taken into the cylinders per minute, an increase in RPM will result in the cylinders being charged oftener, with a consequent increase in the amount of air-fuel mixture taken in per minute. Therefore, power increases as engine RPM increases up to a point, but thereafter power falls off even though the RPM continues to increase. This is due primarily to the three following factors:

1. The size of the inlet port and time that the inlet valve is open. This will admit only a certain amount of air-fuel mixture in a given period of time.
2. The size of the exhaust port and the time that the exhaust valve is open. This permits only a certain amount of exhaust gas to be pushed out in a certain period of time. As engine RPM increases, the time that these ports remain open becomes less and less.
3. Friction loss. Friction losses increase with an increase in RPM. It requires a greater fraction of the indicated mean effective pressure to move the engine parts at higher speed, which means that brake mean effective pressure (BMEP) and consequently brake horsepower (BHP) will be lessened.

The mean or average pressure exerted on the surface of the piston head during the power stroke is an important factor affecting the horsepower output of an engine. In combination with the amount of total piston area and other factors, the pressure on the pistons during the power stroke directly affects the torque or twisting moment exerted by the propeller shaft. Since the brake horsepower developed by the engine is a function of torque and RPM, the mean effective pressure on the piston is a direct factor in the production of power. Only a part of the total pressure exerted on the piston is delivered to the propeller shaft in the form of brake horsepower. Part of the pressure is required to overcome friction and other power losses in the engine. To distinguish between the total mean pressure available and the mean pressure converted into brake horsepower, two terms are in common use–indicated mean effective pressure (IMEP) and brake mean effective pressure.

Indicated mean effective pressure can be calculated from an indicator card which is a chart of the pressures inside the combustion chamber of the complete operating cycle of the engine.

BMEP OR TOP

The brake mean effective pressure (BMEP) or torque oil pressure (TOP) can be calculated once the brake horsepower of the engine is determined by a dynamometer test or other means. In order to determine the BMEP of an engine, the following equation can be used:

$$\text{BMEP} = \frac{\text{BHP x Constant of the engine}}{\text{RPM}}$$

By substituting the TOP constant in place of the BMEP constant, the same formula can be used for determining the TOP, therefore,

$$\text{TOP} = \frac{\text{BHP x Constant of the engine}}{\text{RPM}}$$

Most of the large Navy engines have a torque indicating system installed. The torquemeter system is contained in the front crankcase section of the R-3350 engine. It is connected by passages to a torque transmitter, located in the accessory section of the engine, then electrically to a gage in the cockpit, which registers, in BMEP or TOP, the power being delivered to the propeller shaft of the engine.

The ADR assigned as a plane captain or flight engineer will be concerned with calculating brake horsepower (BHP). The following equations can be used to calculate BHP using BMEP or TOP constants.

$$\text{BHP} = \frac{\text{BMEP x RPM}}{\text{Constant}}$$

$$\text{BHP} = \frac{\text{TOP x RPM}}{\text{Constant}}$$

The constants used for the R-3350 engine are 236 for BMEP and 142 for TOP. By referring to the appropriate Service Instructions Manual the constants can be found for the engine concerned.

MAINTENANCE

Reciprocating engine repair is very important to a squadron in accomplishing its mission and maintaining high aircraft availability. The ADR is required to replace various componets, make adjustments, and even make minor repairs. In performing these tasks the ADR will contribute a great deal to the availability of assigned aircraft, provided he uses the approved methods in accomplishing each assigned task. There is an old adage, "Why is there never enough time to do a job right, but always time to do it over." Lost time in this modern Navy is lost availability.

COMPRESSION TESTS

Cylinder compression, which determines the engine's power, depends upon the proper functioning of the valves. Although it is possible for the engine to lose compression for other reasons, low compression for the most part can usually be traced to leaky valves. Conditions which will affect engine compression are:

1. Incorrect valve clearances.
2. Worn, scuffed, or damaged pistons.
3. Excessive wear of piston rings and cylinder walls.
4. Burned or warped valves.
5. Carbon particles between the face and the seat of the valve or valves.
6. Early or late valve timing.

Cylinder compression in aircraft engines is checked with a compression tester. The S1 type is the only authorized tester for reciprocating engines. The tester is a two-gage type which checks cylinder sealing by applying low pressure air to the cylinder with the piston at top center and checking for the minimum acceptable pressure.

The procedure for use of the S1 type compression tester involves the application of air pressure to the cylinder being tested with the piston at top center, using two gages interconnected with a 0.040-inch restriction in the line between gages. The detailed procedure and precautions to be observed are as follows:

1. Perform the compression test as soon as possible after engine shutdown, but not more than 12 hours later in order to provide uniform lubrication of cylinder walls and rings.
2. Remove the front spark plug from the cylinder or cylinders and install the compression testing fixture in the spark plug insert. CAUTION: Take precautions against accidental firing of the engine.
3. Open the bleed valve (shutoff valve) and attach the quick disconnect fitting of the air hose to the fixture in the spark plug insert. This will establish a pressure of 15 to 20 psi in the cylinder when both valves are closed. CAUTION: Take precautions to prevent rotation of the propeller during the compression test.
4. Turn the propeller in the direction of rotation by hand until the piston of the cylinder being tested is coming up on compression stroke against the 15 to 20 psi air pressure and continue turning slowly until the piston reaches top center. Reaching top center is indicated by a flat spot or sudden decrease in force required to rotate the propeller. If the propeller is rotated too far, back up at least one-half revolution and start over again to eliminate backlash in the valve operating mechanism to keep the piston rings seated on the lower ring lands.
5. Close the bleed valve. Check the regulated pressure and adjust to 80 psi, if necessary. CAUTION: Care must be exercised when closing the bleed valve because the air pressure is sufficient to rotate the propeller at least one-half turn if the piston is not at top center.
6. If the minimum acceptable pressure is not achieved, as listed in GREB 207, it is evident there is leakage.
7. The following is a listing of two conditions that may affect the pressure and the means to correct the conditions.

Condition	Correction
(1) Slight carbon buildup between the valve face and seat and also carbon buildup between the valve guide and stem, preventing the valve from closing.	Remove the rocker box covers and after checking for proper valve clearance, tap the rocker arm directly over the valve stem with a fiber drift and a 1- or 2-pound hammer.

(2) The amount of oil film present on the cylinder wall affecting the piston ring seal.	Turn the engine through several revolutions before rechecking compression.

NOTE: The above conditions may exist in varying degrees; however, if the conditions can be corrected the cylinder should not be rejected.

8. Excessive leakage at the exhaust valve can be detected by listening for air leakage at the exhaust port; at the intake valve by escaping air at the carburetor or master control; and past the piston rings by escaping air at the engine breather outlets.

9. If excessive leakage is detected and cannot be corrected by the means listed in the chart above, the cylinder must be replaced.

Three alternate methods of locating leaky intake and exhaust valves are as follows:

1. The wheeze test for locating leaking intake and exhaust valves is also a recommended procedure. In this test, as the piston is moved to top dead center on the compression stroke, the faulty valve may be located by listening for a wheezing noise in the exhaust collector or intake duct, thus indicating air leaking past the respective valve.

2. Another method is to admit compressed air into the cylinder through the spark plug hole. The piston should be restrained at top dead center (compression stroke) during this operation. A leaking valve can be located, as with the wheeze test, by listening for noises in the exhaust collector and intake duct.

3. The third method is described as follows. Just before stopping the engine, turn it up to approximately 1,000 rpm and move the mixture control to IDLE CUTOFF. The engine will turn over 6 or more revolutions after combustion ceases. A burned exhaust valve will be evidenced by a pronounced shush from the stack into which the affected cylinder is exhausting, this sound occurring each second revolution of the engine. When this sound has been heard, pull the engine through by hand and find the approximate source. (The best position for detection is as near the exhaust outlet as possible.) Then test the compression in the suspected cylinders. The cylinder with the faulty value will have less compression than the others. The exact amount of compression lost depends on the degree of burning and will ordinarily be at least 50 pounds.

CYLINDERS

The reciprocating engine cylinders are designed to operate over a specified time before normal wear will be cause for their overhaul. If the engine is operated as recommended and proficient maintenance is performed, the cylinders normally will last until the engine is removed for high-time reasons. It is known from experience that materials fail and engines are abused through incorrect operation; this has a serious effect on the cylinder life. Another reason for premature cylinder change is poor maintenance. Therefore, the Aviation Machinist's Mate R should exert special care to insure that all the correct maintenance procedures are adhered to when working on the engine.

Removal

The reasons for cylinder change are given in table 11-1.

Several other conditions found on inspection of cylinders are causes for removal. They are:

1. Cylinder head cracks. Cylinders may be considered serviceable if they meet the following conditions:

    a. There must be no cracks in rear spark plug area.

    b. There must be no exhaust or oil leakage from a crack.

    c. Logbook entries must be made to identify the cylinder, the cracked area, and the extent of the crack.

    d. Followup inspections must be made at major check periods.

    e. No cracked cylinders are to be installed during line maintenance. Cylinders that show evidence of leakage or exhibit cracks that are too long or too deep should be removed from service.

2. Cylinders involved with burned pistons. An engine in which a piston has experienced a hole burned through the dome or down the side must be rejected.

3. Breakage or loosening of cylinder holddown screws. If at any time after engine operation, one or more of the cylinder holddown

Table 11-1. —Reasons for cylinder change.

Trouble	Probable cause	Remedy
Improper idling of engine.	Sticking valves; low compression in one or more cylinders; broken valve spring.	Replace cylinder.
Engine runs rough.	Dead cylinder.	Cylinder check (magic wand or engine analyzer).
	Sticking valves or valve tappets.	Replace cylinder or valve tappets.
	Low compression.	Check cylinder and replace, if necessary.
	Broken valve spring.	Replace cylinder.
Torching (afterfire).	Inoperative cylinder.	Check cylinder; replace, if necessary.
Loss of compression.	Warped or sticking valves; warped valve seats; or collapsed valve.	Replace cylinder.
	Worn or stuck piston rings.	Locate trouble by compression check; replace cylinder and piston assembly.
	Cracked pistons or cylinders.	Cylinder check; compression check; replace cylinder, if necessary.
Oil loss through engine breather.	Piston-cylinder blowby.	Replace cylinder and piston assembly.
	Hole burned in piston.	Change engine.
Excessive oil consumption.	Worn or broken piston rings; incorrect installation of piston rings; or worn valve guides.	Replace cylinder.
Improper valve clearance.	Stretched valve stem; or valve collapsed.	Replace cylinder.
Damaged intake push rod.	Broken exhaust rocker arm in same cylinder causing excessive pressures.	Replace cylinder and damaged push rod.
Both spark plugs in one cylinder cutting out.	Cylinder pumping oil.	Replace cylinder.

screws are found to be loose or broken at any location, the cylinder involved must be replaced and all holddown screws used on that cylinder scrapped. A tag bearing the reason for removal should be attached to the removed cylinder and the cylinder returned to the Aviation Supply Office for appropriate disposition.

Details for replacing cylinders and piston assemblies are too numerous to be covered in this course; the variety of reciprocating engines also prohibits this coverage. The information and illustrations given are general and apply to the R-3350 engine. Detailed information on specific engines is to be found in the appropriate Service Instructions Manual for each engine.

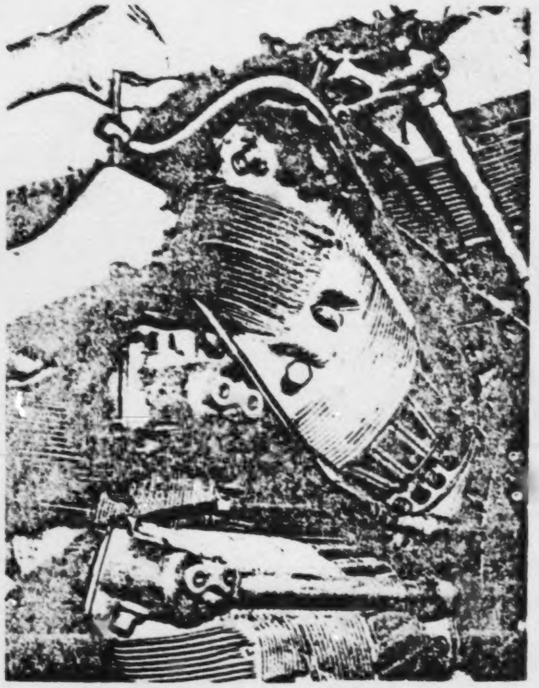
Replacing the cylinder requires removal of the following parts: intake pipes, exhaust pipes, front and rear cylinder intake and exhaust air deflectors, rocker box drain manifold (for lower cylinder), external oil tube (certain cylinders), crankcase main front section oil drain tube (certain cylinders), spark plugs, push rod housings, push rods, and valve tappet sockets and springs, and fuel injection tube, if installed.

NOTE: Insure that the pistion is at top dead center of the compression stroke before removal of push rod housings and push rods to relieve tension on the push rods.

Break the lockwire on the cylinder holddown screws, using a puller. On engines incorporating cylinder holddown screw lock plates, remove the plates. All cylinder holddown screws should be loosened next, using the cylinder holddown screw wrench. (See fig. 11-1.) With the exception of two holddown screws spaced 180° apart, remove all holddown screws with a speed wrench (fig. 11-2). When pneumatic equipment is available, it may be used.

Make sure that the piston is at the top of the cylinder and remove the two remaining holddown screws. Withdraw the cylinder far enough to expose the articulating rod. Hold the rod while the cylinder is removed to prevent it from hitting the crankcase main section. (See fig. 11-3.)

Insert a piston pin removing tool, as shown in figure 11-4, in the inside diameter of the piston pin. Support the piston in a manner to prevent the piston boss from striking the rod and tap the plug from the pin. Install the puller in the piston pin and pull the pin.



AD.106

Figure 11-1.–Loosening cylinder holddown screws.

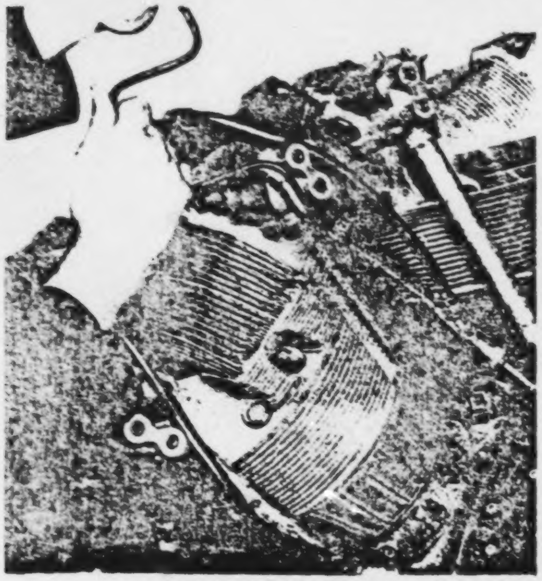
Install a protector, as shown in figure 11-5 (A), on the articulating rod. A master rod guide plate should be installed on the master rod cylinder mounting pad. (See fig. 11-5 (B).)

It is important that the master rod be held near the center of the hole to prevent the bottom rings on adjacent pistons from dropping below their cylinder skirts.

Installation

In order to reassemble and install a cylinder on an engine, a detailed procedure should be followed. This procedure is set forth in the Service Instructions Manual for the particular engine on which the Aviation Machinist's Mate R is working.

The first step is to clean the barrel, flange, and skirt of the cylinder with a clean lintless cloth and Stoddard solvent. Insure that there are no burrs on the cylinder skirt. Apply clean engine oil to the first 4 inches of the cylinder



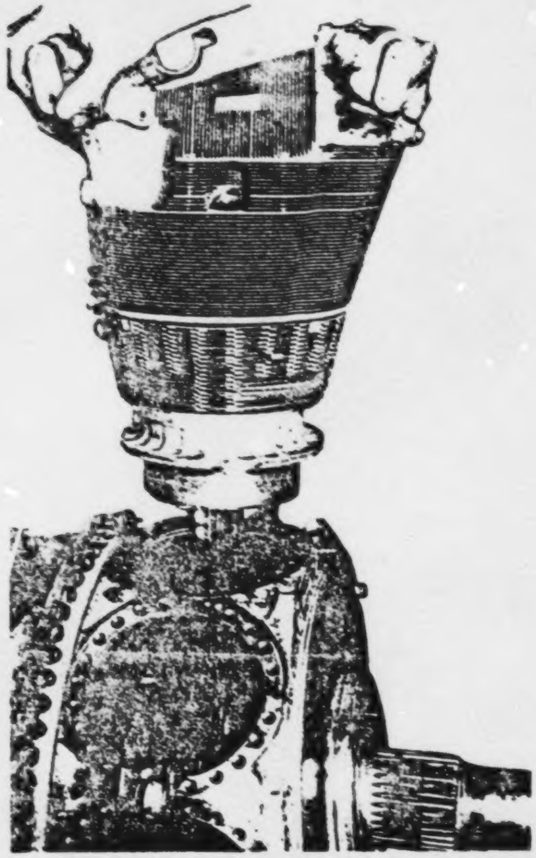
AD.107

Figure 11-2.–Removing cylinder holddown screws.

barrel. Insure that the old oil seal ring is removed from the cylinder skirt. Coat a new oil seal ring lightly with sealing compound (Tite-seal). Install the ring on the skirt adjacent to the mounting flange.

Some cylinder crankcase mounting pads accommodate only 7/16-inch capscrews. Other crankcases accommodate four 7/16-inch capscrews at the crankcase parting line (two on each side) and 1/2-inch capscrews at the other locations on the pad. The 7/16-inch capscrews are available in two hardnesses. The high-hardness capscrews are identified by two shallow slots milled across the top of the head. DO NOT MIX 7/16-inch capscrews of different hardness on a cylinder mounting pad.

Place a spherical washer over each cylinder holddown screw. Apply rubber cement to the first few threads of the holddown screws. Insure that the spherical washer, the neck and the underside of the holddown screw head, and the spherical seat in the cylinder attaching flange are entirely free of cement.



AD.108

Figure 11-3.–Removing cylinder.

Lubricate the pilot diameter of the piston pin plug with clean engine lubrication oil. Use an installing tool to press the piston pin plug into the piston pin, using the installing tool between the plug cap and the arbor press ram. Care should be exercised to exert only sufficient pressure to bottom the shoulder of the plug against the end of the piston pin. When installing the piston on the rod, be sure that the piston pin is installed with the piston pin plug facing the propeller end.

Remove the protector from the articulated rod or the master rod guide plate from the cylinder mounting pad, as applicable. Position the correct piston for the cylinder on the rod and slide the unplugged end of the piston pin through the piston and rod. Bottom the pin against the boss within the piston. (See fig. 11-6.)

Insure that piston rings No. 1 through No. 4 are installed with the side marked TOP facing toward the top of the piston and ring No. 5 (bottom ring) is installed with the side marked TOP

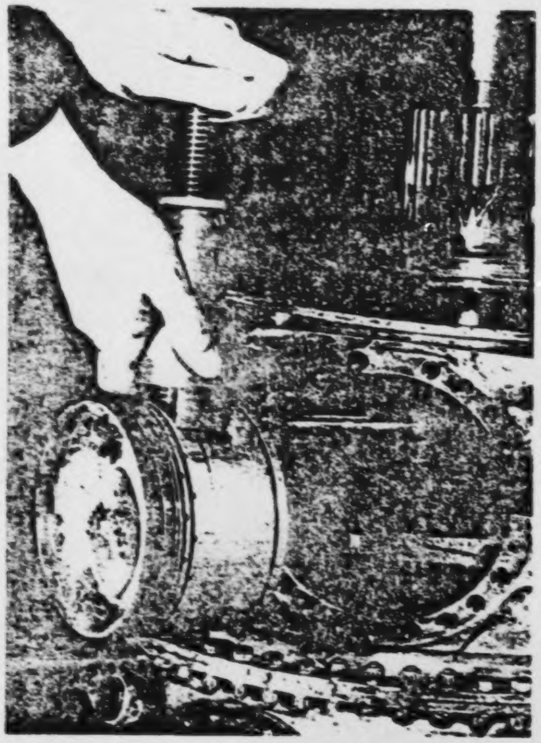


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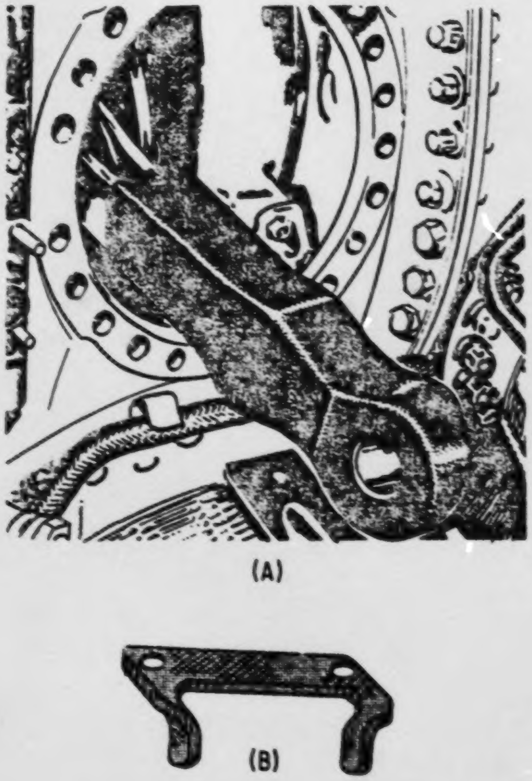
Figure 11-4.–Pulling piston pin.



AD.110

Figure 11.5.–(A) Protector installed for the articulating rod; (B) guide plate for master rod.

facing down, away from the top of the piston. (See figure 11-7 for proper ring configuration. Refer to the latest revision of the applicable General Reciprocating Engine Bulletin (GREB 114) for engines with chrome-plated cylinders installed.

NOTE: The No. 5 ring (bottom ring) is installed with the side marked TOP facing down toward the bottom of the piston to enable the ring to scrape oil toward the cylinder dome.

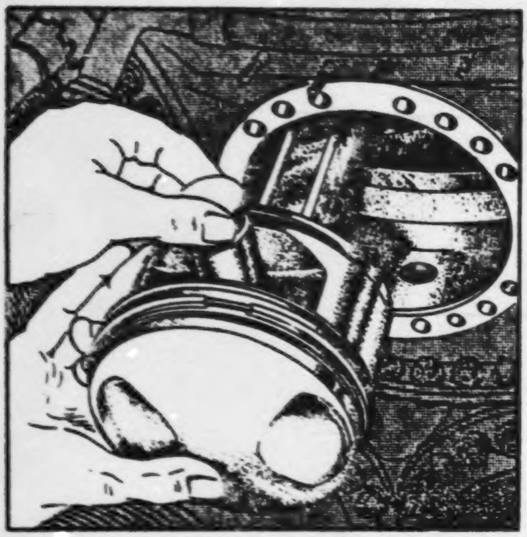
Coat the piston and rings with castor oil, unless the cylinder barrel is chrome plated; use clean engine oil for chrome-plated cylinders. Stagger the gaps 180°. Compress the top four piston rings, using a clamping tool, and carefully slide the cylinder over it. Loosen the clamp and reposition on bottom ring. There is no positive retention of the piston pin until the cylinder is installed. The piston pin plug will then bear against the cylinder wall, holding the pin in place. Recheck to insure that the piston pin has been properly installed. Slide the cylinder down over the bottom ring and remove the clamp. (See fig. 11-8.)

Position the cylinder against the mounting pad and install two cylinder-to-crankcase locating screws, 180° opposite. Then start 19 cylinder holddown screws.

Tighten the two cylinder-to-crankcase locating screws with a torque wrench. Run the 19 cylinder holddown screws in with a speed wrench or a pneumatic wrench. Using a torque wrench, tighten the 19 screws in a pattern to insure uniform loading around the flange. (See fig. 11-9.)

Remove the two locating screws and install the regular thread holddown screws. Tighten the screws to the correct torque value.

Lockwire the screws in groups of five or six unless lock plates are used to secure the screws.



AD.111

Figure 11-6.—Installing piston and piston pin.

Several GREB's give information on cylinder. One example to show their importance follows. It concerns chrome-plated cylinders. Among other items of importance, it gives identification of chrome-plated cylinder bores and piston rings installation for chrome-plated cylinders. These two items are mentioned because of their importance when changing cylinders and pistons of an engine.

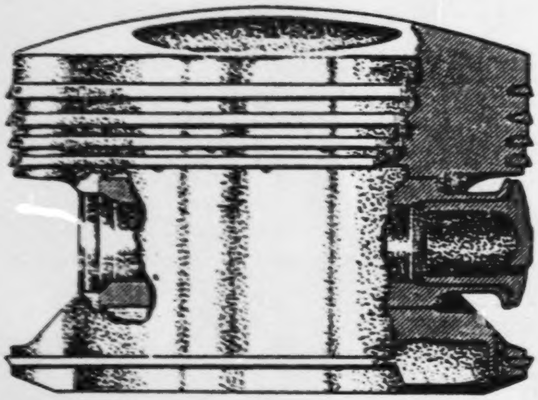


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Figure 11-7.–Piston pin and piston rings installed (cutaway view).

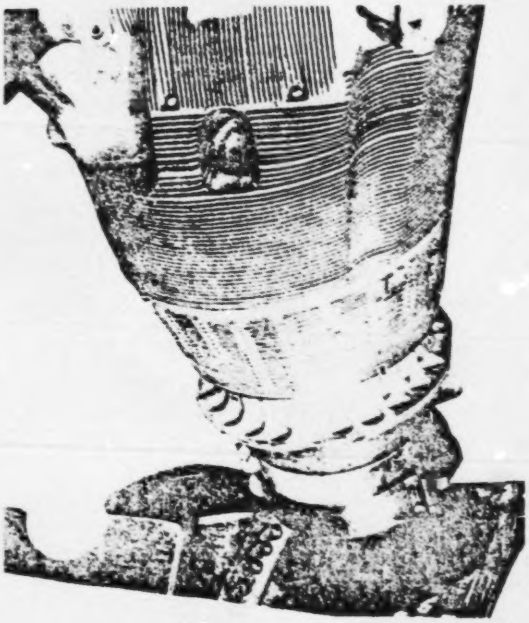

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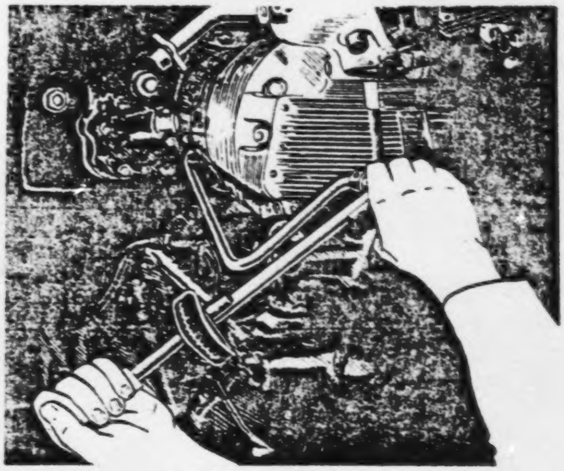
Figure 11-8.–Sliding cylinder over bottom ring of piston.



AD.114

Figure 11-9.–Tightening cylinder holddown screw with a torque wrench.

VALVES

The intake and exhaust valves used in aircraft reciprocating engines open and close the passageways which admit the air-fuel mixture, or air alone, and release the exhaust gases. Two valves are used in each cylinder: intake and exhaust. Valves are usually made of chrome-nickel steel or tungsten steel alloy. Both metals retain their strength at relatively high temperatures.

Components

The valve operating mechanism consists of those components necessary to open and close the valves at the correct points in the operating cycle.

In a radial engine, a cam ring, on which there are cam lobes, rotates to actuate cam followers or tappets. Each cam follower actuates a push rod, causing it to move against a rocker arm. The rocket arm action opens the valve. The valve is closed by spring tension provided by double concentric springs. These components may be seen in figure 11-10.

The cam ring in mounted concentrically with the crankshaft and is driven by the crankshaft at a reduced speed through one or more cam reduction gears. The cam ring has two parallel sets of lobes spaced around the outer diameter; one set, or cam track, for the intake valves, and the other set for the exhaust valves.

The cam follower assembly consists of a tappet; a tappet guide; a tappet roller; a tappet ball, or push rod socket; and a tappet spring. The tappet assembly converts the cam lobe contour into reciprocating motion and transmits this motion to the push rod.

The push rod is constructed of hollow steel tubing with hardened ball-shaped ends. The push rod transmits motion from the tappet assembly to the rocker arm. The push rod is enclosed in a tubular housing that extends from the crankcase to the cylinder head.

The rocker arm is mounted on a shaft in the rocker box, which is in the cylinder head. The rocker arm transmits the motion of the push rod to the valve tip. The rocker arm has an adjusting screw which provides for adjustment of the clearnace at the valve tip. The clearance is provided to allow for heat expansion, enabling the valve to close fully.

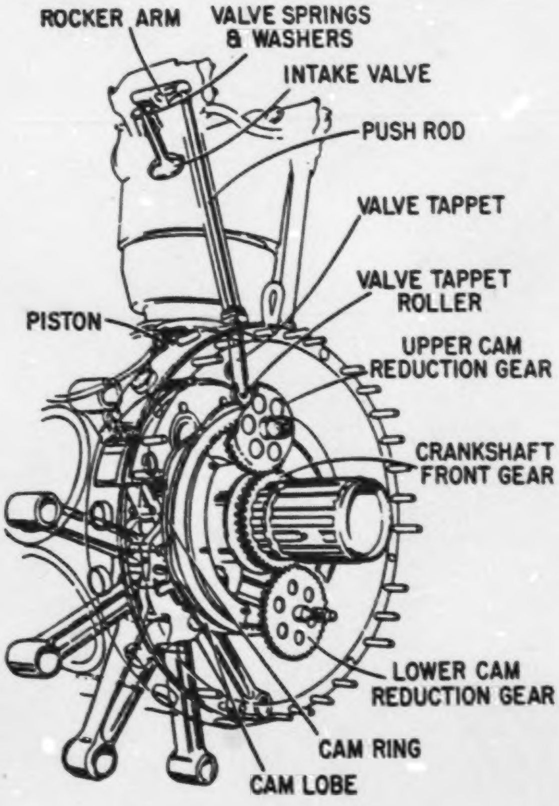


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Figure 11-10.–Valve operating mechanism.

The valve spring assembly consists of two or more valve springs the necessary valve spring retaining washers, and the locking devices for securing the spring assembly to the valve. These locking devices are known as keepers or split keys, and are generally made in the form of a split cone. The function of the valve spring assembly is to close the valve and hold it securely on the valve seat.

Clearance Adjustment Procedures

A slight clearance must be provided between the rocker arm and the valve tip. If there were no clearance, the valve could be held slightly off its seat when it should be closed. This condition would cause improper operation of the engine.

Adjustment of valve clearances should be made only when the engine is cold. Since the adjustment procedures and valve clearances vary for different engines, the appropriate Service Instructions Manual should be referred to for this information.

It is very important that the valve clearance adjustments be properly made; otherwise reduced power output and possible backfiring into the induction system might occur.

The valve clearance adjustment procedures for the R-3350 engine are discussed.

The Aviation Machinist's Mate R should first remove the rocker box covers from the cylinders on which the valves are to be adjusted. One spark plug may be removed from each cylinder to relieve compression. After removing the spark plugs, install screened protective plugs in the spark plug busings. The tools required for adjusting the valves on any engine are listed in the Service Instructions Manual for each engine.

To adjust the valve clearances on an individual cylinder, proceed as follows:

1. Turn the propeller shaft in the direction of rotation until the piston in the cylinder in which the valves are to be adjusted is at top center on the compression stroke. Raise the adjusting screw end of the rocker arm slightly to insure that the valve tappet ball socket slides freely in its guide.
2. With both valves in the cylinder closed, loosen the adjusting screw lock screw with a suitable box wrench. (See fig. 11-11.)
3. Turn the adjusting screw out one or two turns with a broad-blade screwdriver or Allen head wrench, as applicable.
4. Insert a 0.010-inch feeler gage between the valve tip and the adjusting screw and turn the adjusting screw in with a broad-blade screwdriver. (See fig. 11-12.) When any further turning of the screw would open the valve slightly, there will be an appreciable increase in torque and the feeler gage will be tightly clamped. Loosen the screw only enough to allow the feeler gage to be withdrawn.
5. Tighten the adjusting screw lock screw to 425 to 450 inch-pounds.
6. With a screwdriver and a torque wrench on the adjusting screw, check the clamping action of the lock screw, as shown in figure 11-13. The adjusting screw must not move when 450 inch-pounds of torque are applied. Do not exceed 450 inch-pounds to obtain the breakaway torque.

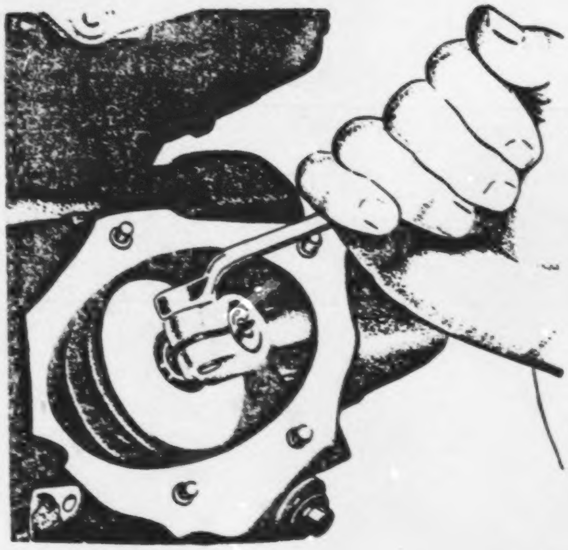

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Figure 11-11.–Loosening adjusting screw lock screw.

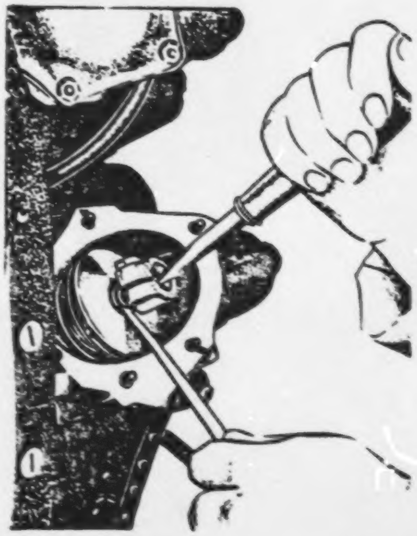

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Figure 11-12.–Feeler gage between valve tip and adjusting screw.

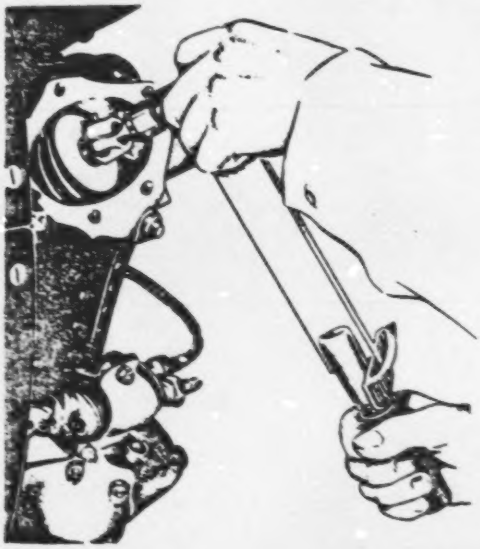

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Figure 11-13.—Checking breakaway torque on adjusting screw.

7. Recheck for lock screw clamping action.

When it is necessary to adjust valve clearances on all the cylinders, remove and replace the following parts: rocker box drain manifold, all rocker box covers, and the front spark plug from each cylinder.

Establish true top dead center on the compression stroke with a piston position indicator. This is illustrated in figure 11-14 and also in chapter 9. A timing disc or protractor should be installed on the right-hand fuel pump drive pad with its pointer setting at the zero indication (fig. 11-15). After true top dead center has been established, it should be rechecked prior to making any adjustment on the valves, since slippage of the adjustable arm on the piston position indicator or binding of the pointer on the timing disc could cause an error in the reading obtained. After this has been accomplished, proceed to adjust all the valves as follows:

1. Rotate the crankshaft until the pointer on the protractor (timing disc) indicates zero with all backlash removed from the gear train.
2. Cylinder No. 1 is then in position for valve adjustment.
3. Loosen the adjusting screw lock screw, using a suitable box wrench. Turn the adjusting screw out one or two turns. Using a 0.010-inch

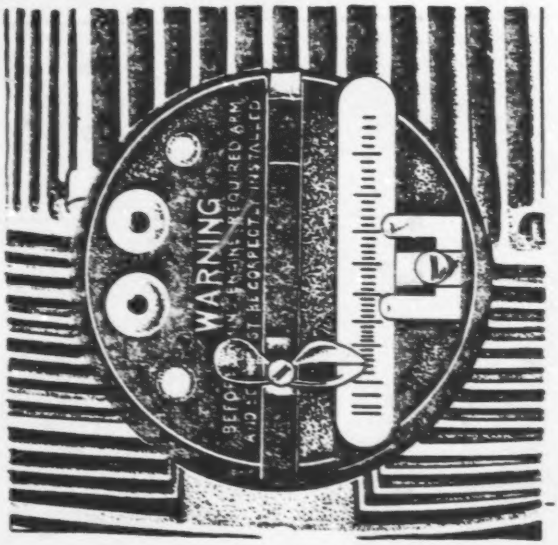

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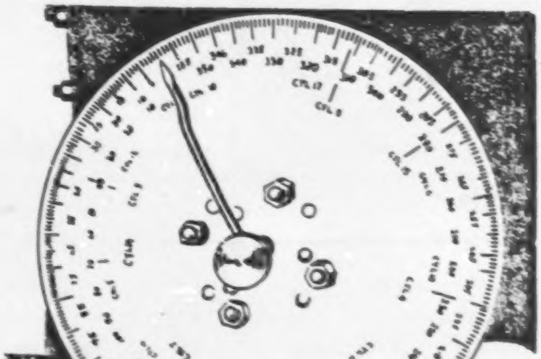
Figure 11-14.—Piston position indicator installed in No. 1 cylinder.



AD.120

Figure 11-15.—Timing disc installed on the fuel pump mounting pad.

feeler gage, insert it between the valve tip and the adjusting screw tappet, and turn down on the adjusting screw until the feeler gage is tightly clamped. Loosen the adjusting screw only far enough to allow the feeler gage to be withdrawn. Tighten the adjusting screw lock screw enough to hold the adjusting screw in this position.

4. Rotate the crankshaft in the direction of rotation until the timing disc pointer indicates 31 degrees on the disc. This will position the piston in cylinder No. 12, at the top center on the compression stroke. Adjust the valves in this cylinder as described in step 3.

5. Adjust the valves in the remaining cylinders in the order shown in table 11-2.

Table 11-2.—Valve adjusting order and timing disc readings.

Cylinder number	Pointer reading on timing disc (degrees)
1	0
12	31
5	80
16	111
9	160
2	191
13	240
6	271
17	320
10	351
3	*400 (360 + 40)
14	431 (360 + 71)
7	480 (360 + 120)
18	511 (360 + 151)
11	560 (360 + 200)
4	591 (360 + 231)
15	640 (360 + 280)
8	671 (360 + 311)

*Since the timing disc has only 360° graduations (ONE complete revolution), and since the completion of all four strokes in all cylinders requires 720° of crankshaft rotation (TWO complete revolutions), all piston positions set at more than 360° require that the timing disc pointer rotate past the 360° mark to the number of degrees indicated in parentheses in the table.

6. Conduct a second valve clearance check and loosen to 0.010 inch any screw below 0.007-inch clearance.

7. Using a torque wrench, tighten the adjusting screw lock screw. Torque to 425-450 inch-pounds. Check the breakaway torque of 450 inch-pounds on the adjusting screw with the proper driver on Allen head wrench. (See fig. 11-13) The adjusting screw must not move when 450 inch-pounds of torque are applied. Do not exceed 450 inch-pounds to obtain breakaway torque. If the adjusting screw turns when the breakaway torque is applied, a related discrepancy may exist in the affected parts.

8. Conduct a third valve clearance check and again loosen any adjusting screw below 0.007-inch clearance and any excessive loose clearance above 0.017 inch. The clearance will be brought down by the amount that will not result in less than 0.007-inch clearance on a previous tighter cam location.

9. Remove the timing disc pointer and the timing disc. Use a new gasket and replace the fuel pump or substituting cover, washers, and self-locking nuts.

Troubleshooting

This section outlines the most common symptoms of valve and valve operating mechanism troubles, their possible causes, and remedies. Locating and correcting these troubles should be accomplished by first studying the symptoms carefully and then checking each possible cause, beginning with the most probable, until the exact cause of the trouble is determined. Because the symptoms of some troubles are revealed in only one range of engine speed, the engine's operation should be critically observed at low, medium, and high speeds whenever possible.

Before attempting to work on an engine which has been reported as faulty in flight, consult the pilot's flight report for any pertinent information which might give a clue as to the cause of the trouble.

Whenever irregular ground or flight operating characteristics can definitely be attributed to engine malfunctioning or whenever replacement of an engine part requiring considerable labor is anticipated, it is advisable to remove the main oil strainer, drain the sump, and in-

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spect the oil and strainer for metal particles before attempting to locate the trouble or replace any parts. This procedure may eliminate unnecessary labor.

Table 11-3 shows that the most common troubles with valves and valve operating mechanisms are improper valve clearances, broken valve springs, and sticking valves.

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Table 11-3. —Valve and valve operating mechanism troubleshooting.

Trouble	Cause	Remedy
Improper idling.	Improper valve clearance.	Adjust valve clearance.
	Sticking valve.	Change cylinder assembly.
	Broken valve springs.	Change cylinder assembly.
Excessive cylinder head temperature.	Incorrect valve clearance.	Adjust valve clearance.
	Improper valve operation.	Check valve operation; check for improper valve clearances; replace cylinder if necessary; adjust valves.
Loss of compression.	Broken valve springs.	Replace cylinder assembly.
	Sticking valves.	Replace cylinder assembly.
	Warped or pitted valve seat; excessive carbon or foreign matter between valve and seat.	Change cylinder. Remove carbon by placing a fiber drift on rocker arm directly over valve stem and strike it with a 1- to 2-pound hammer. NOTE: The extremely high temperatures at which the valve operates sometimes causes the head or the stem to become warped. Either condition will prevent the valve from closing tightly. Often when a valve has been burned, it will be found to be warped.

Table 11-3.—Valve and valve operating mechanism troubleshooting—Continued.

Trouble	Cause	Remedy
Loss of compression—Continued.	Valve stem covered with scale.	Clean with emery cloth. Replace if necessary. NOTE: Scaling is the result of burning, although it is mild in form. When this occurs, small flakes form on the valve seat. These are blown away by the exhaust gases, which results in the valves being rough and uneven, destroying perfect compression.
Loss of power.	Sticking valves.	Lubricate sticking valve. Replace cylinder, if necessary.
	Broken valve springs.	Replace cylinder.
	Broken or bent parts in valve system.	Replace cylinder and the discrepant valve train parts.

CHAPTER 12

PROPELLER OPERATION AND MAINTENANCE

The propeller converts the power output of the engine into forward thrust needed to move the aircraft through the air.

There are two general types of propellers in use today–the fixed-pitch and the controllable-pitch. The fixed-pitch type is used on small liaison aircraft. It is usually a 2-blade propeller and is often made of wood, although some are made of steel or aluminum alloy. The controllable-pitch propeller permits adjustment of the blade angle during operation of the engine in the air or on the ground. Blades are usually made of steel or aluminum alloy. The pitch changing mechanism may be operated hydraulically or electrically.

Due to the limited use of the fixed-pitch propeller, only the controllable-pitch type propeller is discussed in this training manual.

Before discussing the propeller, it would be well to note its principal parts as well as the terms used in the discussion. The parts and terms described in the following paragraphs are illustrated in figures 12-1 through 12-4.

1. BLADE. One arm of a propeller from the butt to the tip. Propellers may have two or more blades. (See fig. 12-1.)
2. BLADE BACK. The surface of the blade that can be seen by standing in front of the aircraft. (See fig. 12-1 and 12-2.)
3. BLADE FACE. The surface of the blade (fig. 12-1) which can be seen by standing directly behind the airplane.
4. SHANK. The thickened portion of the blade (figs. 12-1 and 12-3) near the hub of the propeller. The shank is sometimes referred to as the ROOT.
5. TIP. The portion of the blade (figs. 12-1 and 12-3) farthest from the hub.
6. HUB. The central portion of the propeller. (See fig. 12-1.) It is fitted to the propeller shaft and secures the blades by their roots.
7. LEADING EDGE. The forward or "cutting edge" of the blade (fig. 12-1) that leads in the direction the propeller is turning. The other edge (rear edge) is called the TRAILING EDGE.
8. BLADE STATIONS. Reference lines, usually designated from measurements made from the center of the hub. These station numbers are used to discuss and locate positions on the propeller blade, and are usually designated at 6-inch intervals. (First station is normally 12 inches from the center of the hub.) Figure 12-3

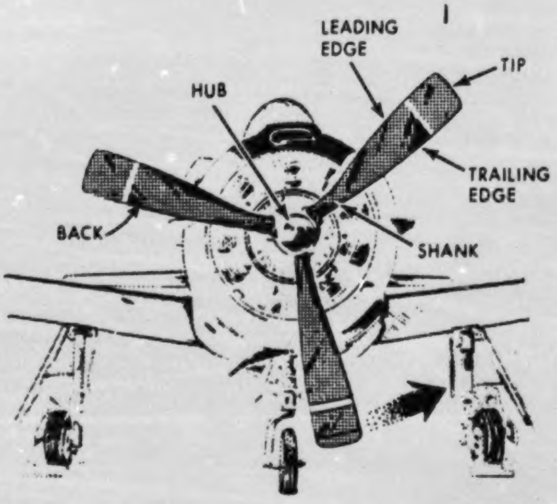

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Figure 12-1.–Propeller nomenclature.

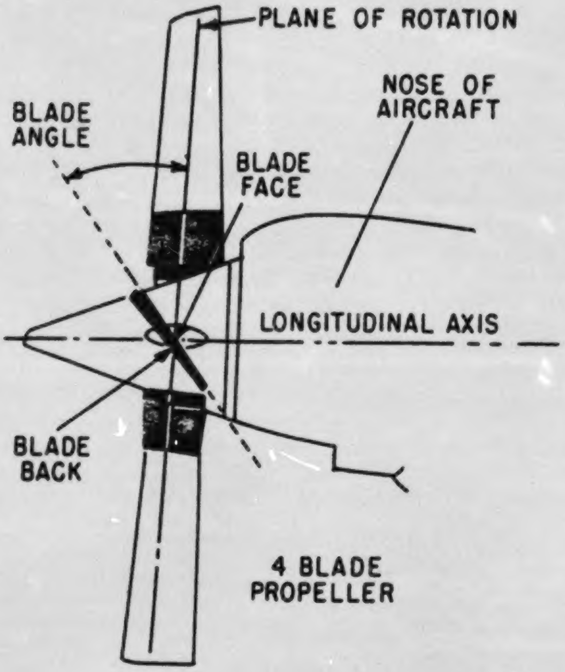
PLANE OF ROTATION
NOSE OF AIRCRAFT
BLADE ANGLE
BLADE FACE
LONGITUDINAL AXIS
BLADE BACK
4 BLADE PROPELLER

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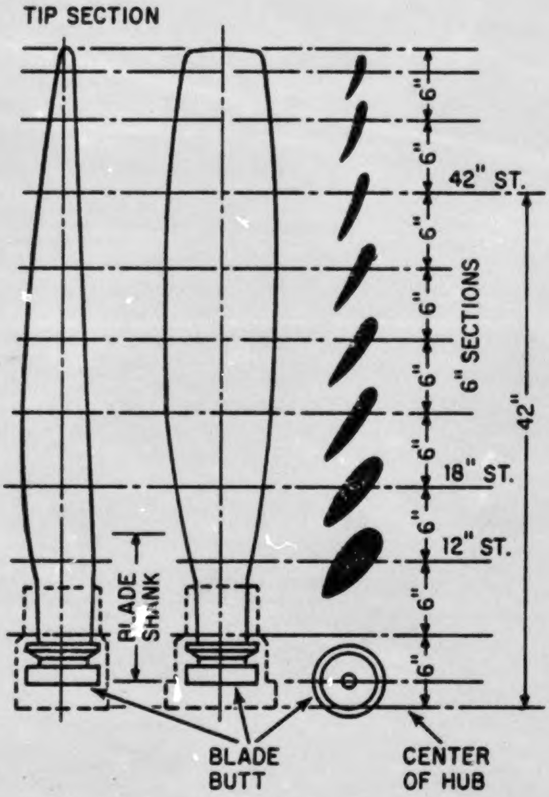
Figure 12-2.–A 4-blade propeller.


TIP SECTION
6"
6"
6"
6"
42" ST.
6"
6"
6"
6"
6"
6"
6" SECTIONS
42"
18" ST.
6"
6"
12" ST.
BLADE SHANK
6"
6"
BLADE BUTT
CENTER OF HUB

AD.123

Figure 12-3.–Blade stations.

shows the blade stations of a typical propeller blade.

9. PROPELLER RETAINING NUT. The nut that locks the hub to the propeller shaft. It is part of the propeller rather than of the engine.

10. BLADE ANGLE (PITCH). The angle formed by the chord of a section of the blade and a plane perpendicular to the axis of rotation. (See fig. 12-4.) The blade angles shown in figure 12-4 are selected to illustrate those of a typical propeller. These angles will vary with different propeller installations.

11. FEATHERING. Special feature incorporated in most propellers used on multiengine aircraft. The purpose of the feathering feature is to reduce the drag of a windmilling propeller on a dead engine, and to stop rotation to prevent further damage. Figure 12-4 illustrates a feathered propeller.

12. REVERSING. A reversing propeller is one in which provisions are made for obtaining a negative blade angle. With a negative angle, a propeller produces a thrust which acts in the opposite direction to that normally produced by the propeller in flight.

Reverse thrust is used during landing of large aircraft in reducing the length of the landing roll. This is a safety feature when it is necessary to use short or icy runways.

OPERATING PRINCIPLES

An aircraft propeller is an engine-driven device designed to impart motion to an aircraft. The primary function of the propeller is to push or pull the aircraft through the air. It converts the rotary force developed in the engine into a pulling force acting on the aircraft, which it moves through the air in the same manner in which propeller blades of another type drive boats through the water.

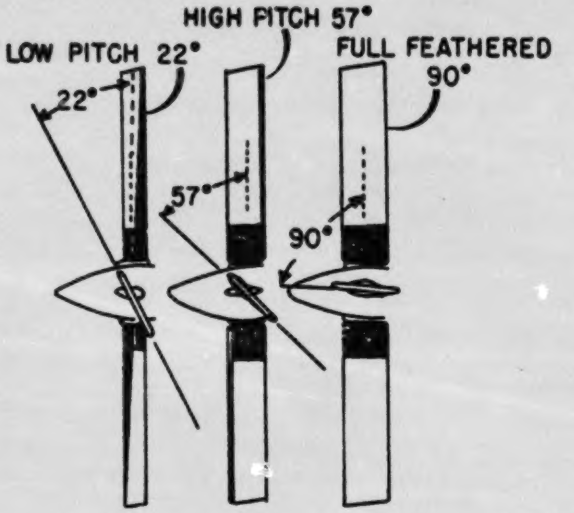


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Figure 12-4.–Propeller angles.

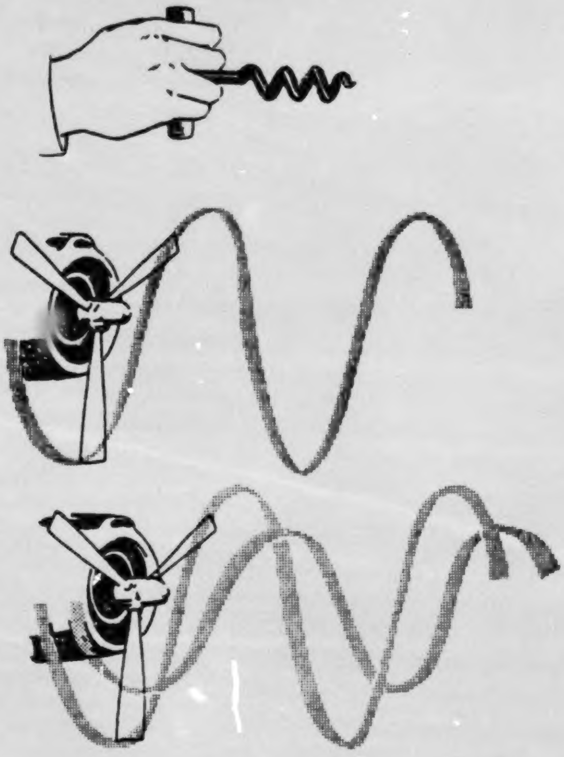

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Figure 12-5.–Propeller action.

A propeller is essentially a "rotating wing," or airfoil. In principle, a propeller is equivalent to a screw. During each revolution through which a screw is rotated, it moves forward a certain distance. (See fig. 12-5.)

When the aircraft engine turns the propeller, relative motion is developed between the wing-like propeller blades and the air. As it pulls itself through the air, the propeller carries along anything that is attached to it, within the limitations, of course, of the power developed. The faster the propeller spins (within certain limits), the greater is the resulting pull (or thrust).

The first propellers were FIXED-PITCH. These were designed mainly to get the aircraft off the ground. The pitch (blade angle) was small so that the engine could quickly turn over to its full rpm and utilize its full horsepower for takeoff. Once an aircraft with a fixed-pitch propeller having a low blade angle is in the air, its forward speed is limited because the propeller will turn too fast to bite efficiently through the onrushing air. As a result, the engine must be throttled to prevent excessive overspeeding.

The first improvement over the fixed-pitch propeller was the GROUND ADJUSTABLE-PITCH type. On this type the blade angle (pitch) could be changed or adjusted on the ground by manually twisting the blades in the hub to the desired angle. When the angle was increased to improve cruising conditions, takeoff conditions suffered. Taking an aircraft off the ground with the propeller at a high blade-angle position is much the same as setting a car into motion in high gear. The engine is not able to produce full horsepower because the high blade angle loads the propeller too much to enable it to turn over at the full rpm of the engine.

The first improvement in design that met the apparent defects of the fixed-pitch propeller was the two-POSITION propeller. It enabled a pilot to use a low blade angle (high rpm setting) for takeoff, climb, and necessary operational acceleration; and then to change the propeller blade angle in flight to a higher blade angle (low rpm setting) for cruise. With this propeller, full engine rpm could be developed for takeoff, while increased aircraft speed could be accomplished at cruise with a decrease in engine power because the high-pitch propeller takes larger bites out of the air.

The two-position propeller did not, however, produce the most efficient and economical use of engine horsepower for all the numerous intermediate flight conditions encountered by aircraft.

Constant-speed propellers were eventually designed to automatically maintain a preselected rpm. With the constant-speed propeller, the selected rpm is maintained by automatically turning the propeller blades to a lower angle, taking a smaller bite of air whenever the load on the engine is increased; for example, when heading the aircraft into a gradual climb at the selected rpm or decreasing the throttle opening. Likewise, the propeller blades move automatically to a higher blade angle and take a larger bite of air whenever the load on the engine is decreased; for example, when heading the aircraft into a nose-down attitude (dive) or increasing throttle opening.

BLADE ANGLE AND ANGLE OF ATTACK (BLADE PATH)

To understand the operation of the propeller, consider first its motion, which is both rotational and forward. Thus, as shown by figure 12-5, a section of the propeller blade, during the lower half of its cycle of rotation, moves downward and forward. As far as the forces are concerned, however, the result is the same as if the blade element were stationary and the air coming at it from a direction opposite its path. The angle at which this air (relative wind) strikes the propeller blade is called the ANGLE OF ATTACK and, as with a wing, the deflection of the air produced becuase of this angle causes the dynamic pressure at the aircraft side of the propeller blade to be greater than atmospheric; thus, it creates thrust.

The shape of the blade element also creates thrust, as it is like the shape of a wing. Consequently, as the air flows past the propeller, the pressure on one side is less than that on the other. As in a wing, this produces a reaction force in the direction of the lesser pressure, and the force is upward (lift). In the case of the propeller, which is mounted in a vertical instead of horizontal position, the area of decreased pressure is in front of the propeller, and the force is in a forward direction (thrust). Aerodynamically, then, thrust is the result of the propeller shape and the angle of attack of the blade.

The BLADE ANGLE is also an excellent method of adjusting the angle of attack. As shown in figure 12-6, the blade angle includes the angle of attack of the propeller. On constant speed propellers then, the blade angle must be adjusted to provide the most efficient angle of attack at all engine and aircraft speeds. The most efficient angle of attack is very small; it varies from 1 to 4 degrees positive angle. The actual blade angle necessary to maintain this small angle of attack varies with the forward speed of the aircraft because the blade motion is the resultant of the forward speed of the aircraft as well as the propeller rotation. Therefore, with constantly increasing aircraft speeds and high altitude operations due to engine supercharging, it is necessary to have a wide range of blade angle settings. This range

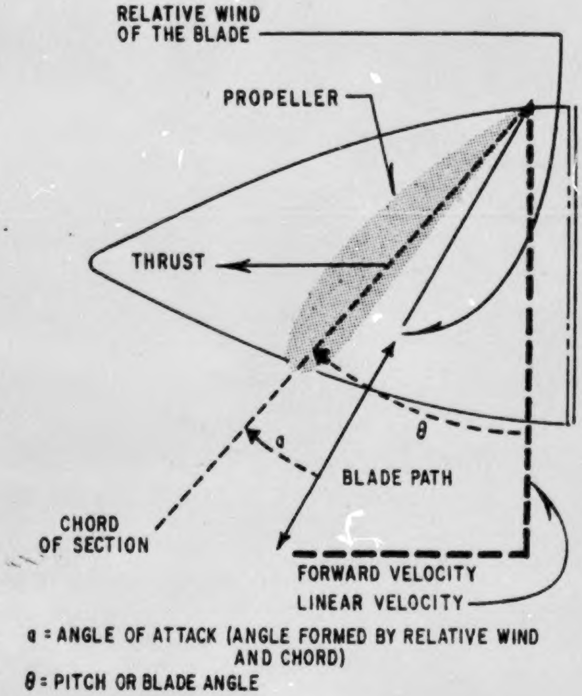

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Figure 12-6.–Aerodynamic factors of a propeller.

of settings must adapt the propeller to conditions encountered in takeoff, climb, and cruising.

During takeoff, when the forward motion of the aircraft is at low speeds and when maximum power and thrust are required, the constant-speed propeller sets up a low propeller blade angle or pitch. The low blade angle keeps the angle of attack (with respect to the relative wind) small and efficient at the low aircraft speed. At the same time, it allows the propeller to "slice it thin" and handle a smaller mass of air per revolution. This light load allows the engine to turn at maximum rpm and to convert the maximum amount of heat energy in the fuel into mechanical energy. The high rpm also creates maximum thrust; for, although the mass of air handled per revolution is small, the number of revolutions per minute are many, the slipstream velocity is great, and with the low aircraft speed, the thrust is maximum.

After takeoff, the speed of the aircraft increases, and the constant-speed propeller changes to a higher angle (or pitch). Again, the higher blade angle, with higher speeds, keeps the angle of attack (with respect to the relative wind) small and efficient. By increasing the mass of air handled per revolution, it decreases the rpm of the engine and reduces fuel consumption and engine wear, but keeps the thrust at a maximum.

For climb after takeoff, the power output of the engine is reduced to climb power by decreasing the manifold pressure and lowering the rpm by increasing the blade angle. The greater mass of air handled per second in this case is more than offset by the lower slipstream velocity and the increase in airspeed (above that prevalent right after takeoff). Hence the torque (horsepower absorbed by the propeller) is reduced to match the reduced power of the engine. The angle of attack is again kept small by the increase in blade angle with an increase in airspeed.

At cruising altitude, when the aircraft is in level flight and less power is required to produce a higher airspeed than is used in climb, engine power is again reduced by lowering the manifold pressure and increasing the blade angle (to decrease rpm). Again, this reduces torque to match the reduced engine power, for, although the mass of air handled per revolution is greater, it is more than offset by the decrease in slipstream velocity and the increase in airspeed. The angle of attack is still small, for here too, the blade angle has been increased with an increase in airspeed.

When it is desired to increase speed from a particular cruise speed, the blade angle is decreased (to increase rpm). Then, as manifold pressure (and power) is increased with the throttles, the constant-speed propeller keeps the rpm at the new setting by increasing the blade angle to increase the mass of air handled per revolution and the power absorbed by the propeller. The greater resulting thrust gives greater aircraft speed. And, of course, the greater blade angle still keeps the angle of attack small and efficient.

FORCES ACTING ON THE PROPELLER

One of the main requirements of any propeller is the ability to withstand severe stresses. These stresses, which are always greatest near the hub, are described in the following paragraphs. Constant-speed propellers utilize some of these natural forces to aid in controlling the propeller blade angles. See figure 12-7, forces acting on propeller blades.

Centrifugal Force

The greatest force acting upon the propeller blade is CENTRIFUGAL FORCE. This force tends to pull the blade of a spinning propeller out of its hub. To prevent the blades from breaking into fragments or flying off into space, the blade is made thicker in cross section near the hub, and the hub itself is made from a strong steel forging.

Thrust Bending Force

There is also a THRUST BENDING FORCE that acts upon the blades. A spinning propeller tries to forge ahead but is held back by the hub and the load of the aircraft it is pulling. The blade tips, which are thinner and lighter than the blade shank, bend forward. The sum of these bending forces on the blades is carried at and near the hub. Hence, the section of the blade at the hub must be proportionately thicker

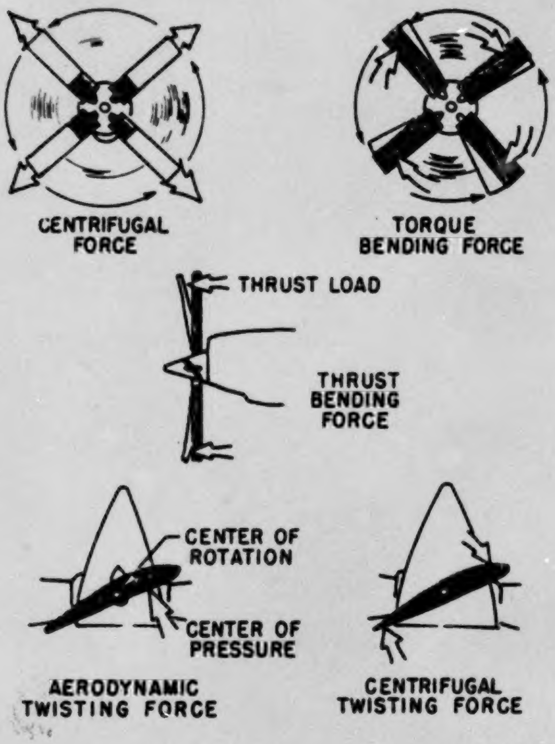

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Figure 12-7.–Forces acting upon propeller blades.

for this reason also. Centrifugal force and thrust bending force oppose each other to some extent.

Torque Bending Force

Another bending force to be considered is the TORQUE BENDING FORCE. The rotation of the propeller is caused by the turning force supplied by the engine crankshaft. Operated in a vacuum, the engine would have an easy task, as air density could be disregarded; however, the blades of the revolving propeller actually meet with varying values of resistance due to the density of the air. This resistance results in a torque on the crankshaft–acting in a direction opposite to the torque power force provided by the engine.

Since every portion of each propeller blade takes some part in producing this torque, the full length of the blade is also subjected to a share of the load. Consequently a blade tends to bend backward throughout its length against the direction of rotation.

Aerodynamic Twisting Force

Another force tries to rotate the blades in the hub so that the blade angle will be increased. This is called the AERODYNAMIC TWISTING FORCE. The point at which this force is exerted most strongly on the chord of the airfoil is known as the center of pressure. Since under normal conditions, this center of pressure is nearer the leading edge of the propeller, the force tends to rotate the blades to a higher pitch. When the aircraft goes into a dive, the center of pressure moves backwards and may even fall behind the center of rotation.

Centrifugal Twisting Force

The CENTRIFUGAL TWISTING FORCE on the blades tends to twist them to a lower pitch angle. This is because all parts of the propeller try to remain in a plane parallel to the plane of rotation of the propeller.

Propeller Vibration

Sometimes, in the face of these forces, a propeller loses some of its rigidity. The result is a FLUTTER, a type of vibration in which the tips of the blades attempt to twist rapidly back and forth while the propeller is turning. Fluttering causes a distinctive noise, which is nearly drowned out by the exhaust noises of the engine. Fluttering will weaken the propeller and may result in structural failure unless detected early so that corrective measures may be taken.

PROPELLER AND ACCESSORIES (43E60 AND 24260)

Before discussing the hydromatic propeller, it should be understood how it receives its designation. A breakdown of the designation for the 43E60 propeller is as follows:

4–Indicates the number of major changes incorporated in the propeller.

3–Number of blades.

E–Blade shank size. (The use of a LETTER here also indicates that the blades are made of aluminum. A NUMBER here would indicate the

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shank size and also that the blades were made of steel, as in model 24260.)

60–Indicates the spline size of the propeller shaft. A number following the "60" indicates the functional and installation characteristics of the propeller.

As the word "hydromatic" may suggest, these propellers are hydraulically operated. A 43E60 propeller is shown in figure 12-8.

The Hamilton Standard Reversing Hydromatic propeller permits constant-speed operation within the limits of the pitch changing mechanism, feathering of the propeller in flight, and reverse pitch operation which greatly improves the ground or water handling characteristics of multiengine aircraft. The two types of propellers discussed in this chapter are the 43E60 and 24260 models, and the model 5U18 double-acting constant-speed control, which is the same for both propellers except for minor modifications.

Instead of the two-slope cams used in the nonreversing type, three-slope cams are used in the reversing model, the third slope being utilized for reverse-pitch operation. A reverse-pitch stop ring limits the blade angle in reverse pitch on the 43E60 and 24260. The low blade angle is limited by a low-pitch stop lever assembly. An oil transfer housing is used to direct oil to and from the propeller. Oil from the constant-speed control is directed to either the inboard or outboard side of the piston through the oil transfer housing.

A cam assembly on the No. 1 blade shank actuates a blade control switch on the barrel during unreversing and unfeather operation. A similar cam on the No. 2 blade on three-bladed propellers and on the No. 3 blade on four-bladed propellers actuates another blade control switch on the barrel during feathering and reversing operations.

A slipring assembly, which provides a means of current transmission from a brush block assembly mounted on the nose section of the engine to the blade control switch on the 43E60 propeller, is mounted on the inboard end of the propeller barrel. The slinger ring is used to distribute anti-icing fluid to the blades and is attached to the slipring assembly. Nozzles direct the fluid to the propeller blades. The 24260 propeller utilizes both face and drum type sliprings for deicing and control of the propeller. Deicing on this model propeller is done electrically, using heaters in the leading edge of each blade.

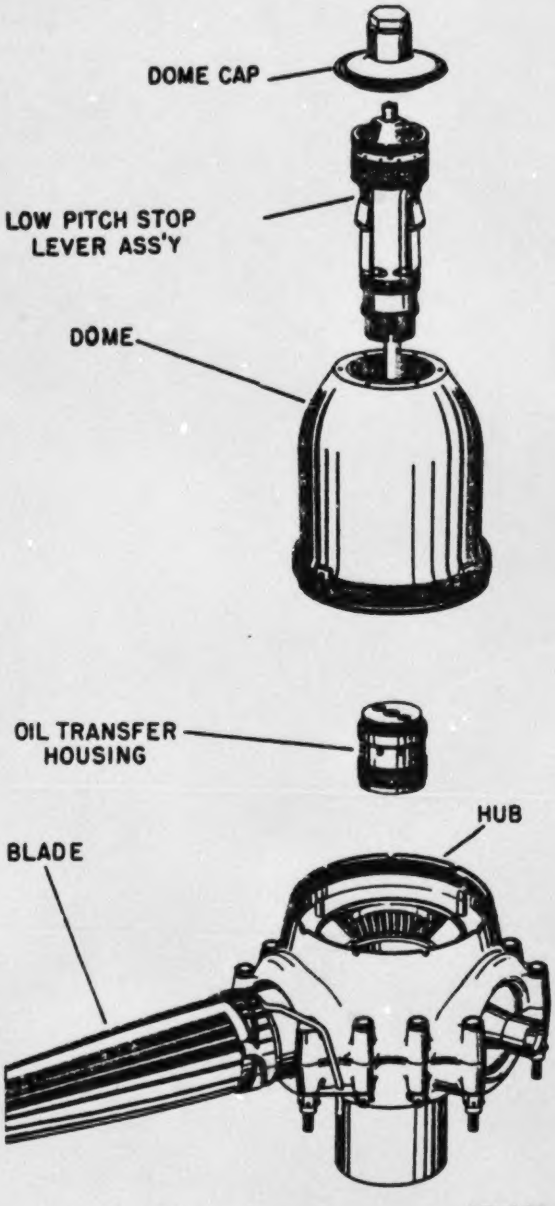

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Figure 12-8.–Model 43E60 propeller.

BARREL ASSEMBLY

The barrel assembly of the 24260 propeller is machined from a one-piece steel forging incorporating a cylindrical central bore and four cylindrical blade arms. The blades are retained by four races of ball bearings. The inner race for these bearings is on the blades, the outer race is in the barrel. Each blade is free to turn about its axis under control of the dome assembly.

The barrel assembly of the 43E60 propeller is made in two pieces, and they are machined and balanced as a pair and kept together for the life of the propeller. The barrel halves are held together by the barrel bolts and nuts. The bolts are hollow and may be filled with lead wool as required to achieve final propeller balance.

CONSTANT-SPEED CONTROL (GOVERNOR)

The double-acting constant-speed control directs oil to either the inboard or the outboard side of the piston in the dome, changing the blade angle in order to maintain the selected engine rpm. It is mounted on the nose section of the engine. The control is made up of three assemblies: head, body, and base. The 5U18 control utilizes a stepmotor electric head to adjust the position of the speeder rack, which in turn changes the compression on the speeder spring. This sets the control to maintain any selected rpm within the operating range of the constant-speed control. The stepmotor electric head may be controlled through a synchronizer system or by a manually operated toggle switch in the cockpit. The electric head eliminates mechanical linkage between the cockpit and the constant-speed control. The constant-speed control also includes flyweights, a gear type pump which produces oil pressure for the operation of the propeller, and various valves which control and direct the flow of oil to the propeller.

An electrically driven auxiliary pump is used as a source of high-pressure oil during the four auxiliary operations. These are the feathering, unfeathering, unreversing, and reversing cycles. The output of the auxiliary pump is led to the constant-speed control and is automatically directed to the proper side of the propeller piston to produce the desired blade angle change.

AUXILIARY PUMP

An electrically driven auxiliary pump is used with those propellers which have feathering and reversing features. It furnishes the high-pressure oil which is necessary during feathering and unfeathering, and reversing and unreversing operation. It is usually mounted in the engine accessory section. An auxiliary pump is shown in figure 12-9.

SYNCHRONIZER

A SYNCHRONIZER is used in many multi-engine aircraft to provide for simultaneous selection of the desired engine rpm for all engines by the manipulation of one control. The rpm of one engine is controlled by the pilot or flight engineer with the master lever. All other engines are slaved to the master engine by the synchronizer.

The synchronizer control utilizes the aircraft's tachometer generators for sensing the difference of engine rpm between the master engine and one or more slave engines. The master engine is used for rpm reference, and the slave engines will follow the master engine whenever they are under control of the synchronizer. A mechanical limiting device in the system limits the synchronizing to approximately 3 percent of the master engine rpm. Thus,

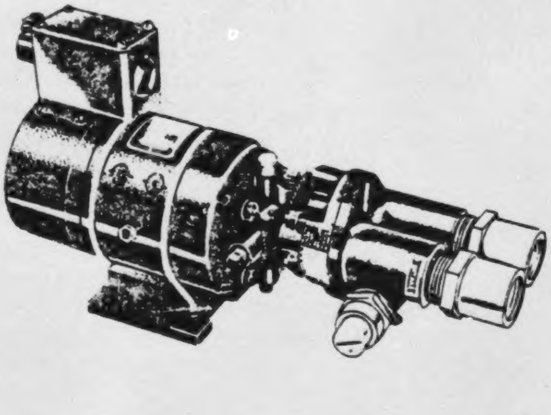

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Figure 12-9.–Auxiliary pump.

an abnormal increase or decrease in the rpm of the master engine or even failure of the master engine cannot cause the slave engine(s) rpm to change beyond this limit. When the master control is advanced to the full increase rpm position (calibrate), the synchronizing feature is cut out so that failure of the master engine on takeoff will have no effect upon the slave engines.

ANTI-ICING AND DEICING SYSTEMS

Protection against icing conditions is provided by either an electrical deicing system or a fluid anti-icing system. Electrical deicing is accomplished by supplying current periodically to a heating element mounted either on or in the leading edge of each blade. A timer unit mounted in the aircraft fuselage controls the deicing current impulses to all propellers. The electrical deicing system allows ice to form on the blades; heat supplied periodically melts the ice sufficiently so that it is thrown off by the centrifugal force acting on the propeller blade. The fluid anti-icing system prevents the formation of ice on the blades. Fluid is distributed to the leading edge of each blade from a hub slinger ring, through tubes, to collectors on each blade. Shoes mounted on the leading edges of blade and cuff (cuffs are added to steel blades to improve aerodynamic cooling of the engine) are grooved to insure distribution of anti-icing fluid over the blade surface.

WARNING: The alcohol used for deicing propellers is isopropyl alcohol and is a deadly poison when taken internally.

PROPELLER OPERATION

The most significant natural force affecting the angle of the propeller blades is the centrifugal twisting moment, which tends to move the blades to a flat or a zero blade angle. This force is always present when a propeller is rotating. Oil pressure from the constant-speed control must overcome the centrifugal twisting moment in order to move the blades to a higher blade angle when desired. Therefore, higher oil pressure is required to increase blade angle.

Oil pressure directed to the outboard side of the propeller piston causes the blades to move toward a higher pitch. The constant-speed control permits oil drainage from the inboard side of the piston when the blade angle is increased. When the blade angle is decreased, the constant-speed control directs oil to the inboard side of the piston and allows drainage from the outboard side of the propeller piston back to the inlet side of the pump in the constant-speed control. Both the pressure oil and the drain oil flow through separate passages in the oil transfer housing, which is screwed into the propeller shaft. The propeller piston may move outboard until a steel sleeve in the piston rests against the levers of the low-pitch stop lever assembly. These levers are held outward by a wedge so that they will engage the sleeve in the piston as the propeller blades reach the low-pitch setting.

When reversing operation is desired, oil pressure from the governor aided by oil pressure from the auxiliary pump actuates the servo unit of the low pitch stop lever allowing the piston sleeve to cam the stop levers down and move forward to the reverse position. This allows the levers to move inward so that the sleeve in the piston may pass by the levers, allowing the blades to go past the low-pitch limit and into reverse pitch. The limit of revers is reached when lugs of the reverse pitch stop ring on the rotating cam come up against lugs on the stationary cam. The No. 2 blade switch, which is actuated by a cam attached to the blade shank of either No. 2 or No. 3 blade, shuts off the auxiliary pump a few degrees before full reverse. Constant-speed control oil pressure then moves the blades into the full reverse position. In the reverse position, slotted ports in the piston sleeve are opened to act as a dump valve, permitting the high oil pressure on the inboard side of the piston to dump through the ports to the outboard side of the piston.

During unreversing, the auxiliary pump furnishes high-pressure oil to the constant-speed control, which directs the oil to the outboard side of the piston and allows oil to drain from the inboard side of the piston. When the piston has moved to a point where the forward end of the piston sleeve is well past the levers of the low-pitch stop lever assembly, the levers are forced outward by spring tension on the wedge and the auxiliary pump is cut off by the No. 1 blade switch. The piston then moves back until the sleeve rests against the levers of the low-pitch stop lever assembly.

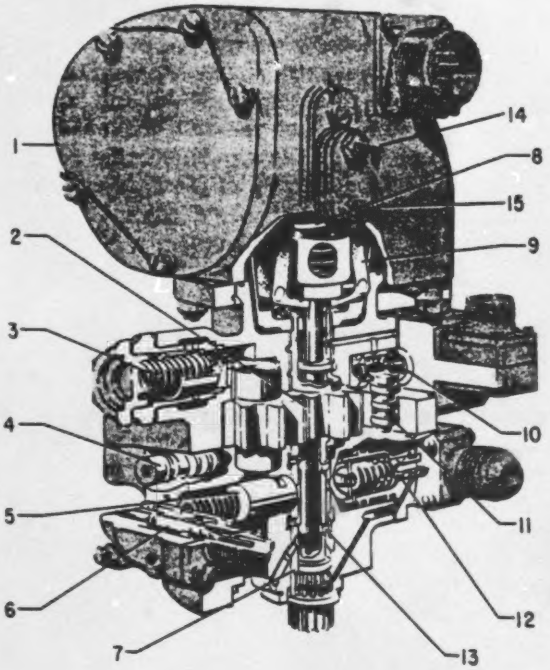
During feathering, the auxiliary pump furnishes high-pressure oil to the constant-speed control, where it is combined with governor oil pressure and is directed to the outboard side of the piston and allows drainage from the inboard side of the piston. This moves the piston inboard and the blades to the feather position. Lugs on the high-pitch stop ring (located on the rotating cam) contact lugs on the stationary cam to stop the blades in the feather position.

For unfeathering, high-pressure oil from the auxiliary pump is supplied to the constant-speed control which directs it to the inboard side of the piston, moving the piston outboard and the blades to a lower angle. As the propeller begins to windmill, the governor boost pump starts to operate and will aid the auxiliary pump to move the blades out of feather. The auxiliary pump is shut off by releasing the feather button when a low rpm is reached. This terminates the unfeathering cycle and allows the constant-speed control to maintain full decrease rpm, which is selected prior to unfeathering.

CONSTANT-SPEED CONTROL OPERATION

A cutaway view of the constant-speed control is shown in figure 12-10.

The stepmotor electric head provides a means of controlling the compression of the speeder spring (8). This compression determines the rpm necessary to hold the flyweights (9) in a balanced or onspeed condition. If compression on the speeder spring is increased, more rpm is required to cause the flyweights to move outward to attain the onspeed condition. If compression is decreased, less rpm is needed.



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1. Electric head.
2. Pump.
3. High-pressure relief valve.
4. Shuttle valve.
5. Low-pressure relief valve.
6. Pressure cutout switch.
7. Drive gear shaft.
8. Speeder spring.
9. Flyweight.
10. Solenoid valve.
11. Selector valve.
12. Auxiliary pressure check valve.
13. Pilot valve.
14. Low rpm adjustment.
15. High rpm adjustment.

Figure 12-10.—Cutaway view of the 5U18 constant-speed control.

Whenever the flyweights move in, the pilot valve (13) moves down. When the flyweights move out, the pilot valve moves up. The position of the pilot valve determines whether oil is directed to the inboard side of the piston or to the outboard side of the piston. During constant-speed operation, the pilot valve (13) is positioned by the forces of the flyweights and the speeder spring. During the four auxiliary conditions, it is positioned by oil pressure in the upper or lower positioning chamber. If the greater force is on the top of the positioning land, the pilot valve will move down. If the greater force is on the bottom of the positioning land, the pilot valve will move up.

The pump (2) boosts engine oil pressure to the pressure required to operate the propeller during constant-speed operation. This does not include the four auxiliary conditions mentioned previously.

The high-pressure relief valve (3) limits the maximum oil pressure for operation of the propeller except when correcting for a normal underspeed condition.

The selector valve directs high-pressure oil to back up the spring side of the low-pressure relief valve during the feathering, unfeathering, reversing, unreversing, and normal overspeed operations. The low-pressure relief valve prevents pressure from building up sufficiently to actuate the servo unit of the low pitch stop lever during ground operation.

During all conditions except normal underspeed, high-pressure oil is directed to the spring side of the low-pressure relief valve by the selector valve, increasing the amount of pressure necessary to open the low-pressure relief valve and allowing pressure to build up until it is relieved by the high-pressure relief valve. By controlling the pressure during a normal underspeed condition, the low-pressure relief valve prevents an inadvertent reversal during ground operation.

The shuttle valve (4) is used to direct high-pressure oil to the plunger side of the pressure cutout switch (16) and return oil to the spring side of the pressure cutout switch. The pressure cutout switch is used on some models to release the feather button after the blades reach the full feather position.

The auxiliary pressure check valve (12) permits the entry of high-pressure auxiliary pump oil into the constant-speed control during the four auxiliary conditions and allows for positive positioning of the pilot valve. It also directs oil to the following places whenever it is in operation: The pressure chamber of the pilot valve, the solenoid valve, and the lower positioning chamber of the pilot valve to create an artificial overspeed for feather and unreverse. It prevents oil from the pump of the constant-speed control from pressurizing the auxiliary pump line during constant-speed operation. It also has a small bleed hole for winterization, which allows a slight amount of control oil to enter the auxiliary line during constant-speed operation. This will prevent oil congealing in this line during cold weather.

The solenoid valve (10), is energized during unfeathering and reversing. It directs oil pressure to the upper positioning chamber causing the pilot valve to move downward, thus creating an artificial underspeed condition.

The low rpm adjustment (14) provides a means of setting the minimum governing rpm by limiting the upward travel of the speeder spring rack.

The high rpm adjustment (15) provides a means of setting the maximum governing rpm by limiting the downward travel of the speeder spring rack.

MAINTENANCE

The maintenance that the ADR performs on the propeller and accessories is limited to servicing, replacement, adjustments, and minor repairs. These are discussed in the following paragraphs.

Propeller

Propeller maintenance consists mainly of removal and installation and minor blade repairs. The installation and removal procedures are discussed in the following paragraphs and blade repair is discussed later in the chapter.

INSTALLATION.–Prior to installation, clean the propeller shaft and engine thrust nut thoroughly. Put a light coat of clean engine oil on the propeller shaft. Install the split rear cone on the propeller shaft, making sure that the surfaces of the cone are dry and clean. Install the spider-shaft spacer on the shaft next to the rear cone. Install the O-ring seal on the shaft next to the spacer. Make pencil marks on the forward end of the propeller shaft to indicate the locations of the locking holes of the shaft. This will facilitate the alignment of one of the slots in the retaining nut with a hole in the propeller shaft.

Place the front cone, propeller retaining nut, and snapring in position in the propeller hub, turning the blades in the hub enough to allow these parts to be inserted past the blade gear segments. As with the rear cone, the surfaces of the front cone should be clean and dry. Apply a thin coat of thread lubricant to the threads of the propeller shaft.

Using a power wrench and sling assembly, lift the propeller onto the shaft. If the propeller shaft has an index spline or an index screw, align the blank spline of the propeller hub with it and slide the propeller back on the shaft. As the propeller is pushed fully into position, tighten the retaining nut by hand to insure that there is not binding or cross threading. Tighten the retaining nut with a short bar until it is snug. Using the power wrench, tighten the retaining nut to the proper torque, and align one of the locking slots in the retaining nut with one of the locking holes in the propeller shaft.

Place the oil transfer housing gasket against the plate inside the propeller shaft. Clean the threads of the oil transfer housing and the internal threads of the propeller shaft and apply a light coat of thread lubricant or engine oil to them. Carefully screw the oil transfer housing into the shaft by hand. Tighten the oil transfer housing to the proper torque, aligning the splines on the housing with the splines on the inside of the retaining nut to receive the lock segment. Install the lock segment and secure with the lock segment lockwire.

NOTE: Never back off the retaining nut to align a slot with a hole. If necessary, back the retaining nut all the way off and retighten to the proper torque. Insert the propeller retaining nut lock through the hole in the shaft and into the slot in the retaining nut.

NOTE: If for any reason the oil transfer tube is removed from the dome or the setting of the low-pitch stop lever assembly is disturbed, these must be reset according to current propeller overhaul instructions. This also applies to the reverse- and high-pitch stop rings. Care must be taken not to damage the oil transfer tube during dome installation and removal.

REMOVAL.–The removal procedures are the reverse of the installation procedures. While the dome or the propeller is being removed, special care must be taken that no electrical circuits are energized from the cockpit. If the auxiliary pump were turned on, a stream of oil (often . hot) under pressure would be sent out the propeller shaft, causing possibly serious injury to anyone in front of the propeller.

After removal, if another propeller is not to be installed immediately, clean, oil, and cover the propeller shaft. If the propeller is to be stored for any length of time, preserve the propeller in accordance with current instructions.

Dome

The dome assembly of a reversing Hydromatic propeller includes the propeller pitch-changing mechanism by means of which oil pressure is transmitted into blade-turning forces. The assembly is illustrated in figure 12-11, and it consists principally of the cams, the piston, and the dome shell.

When the dome assembly is installed in the propeller hub, the STATIONARY CAM provides support for the remaining parts in the dome unit. The stationary cam is rigidly held in the barrel on the stationary cam-locating dowels. The ROTATING CAM is supported within the stationary cam by means of ball bearings, which also serve to take the gear reactions and piston oil force. Piston motion is transmitted through the stationary cam to the rotating cam by means of four or five sets of cam rollers. These are carried on shafts supported by the inner and outer walls of the piston.

Both the stationary and the rotating cams contain inclined cam tracks on which cam rollers operate to transform the back-and-forth motion of the piston into the rotating motion of the rotating cam. The tracks of the stationary cam are inclined in the opposite direction to those on the rotating cam. This arrangement provides twice the rotary motion (for a given straight line motion of the piston) than would be provided with only one cam track.

The rotating cam is machined from steel. The cam tracks and teeth are casehardened for longer wear. The cam tracks are machined in the cylindrical body portion of the cam. These tracks are machined with three slopes, one each for feathering, constant speed, and reversing. (See fig. 12-12.)

The stationary cam is similar in construction to the rotating cam. Its cam tracks are identical in design with those of the rotating cam except that they are inclined in the opposite direction.

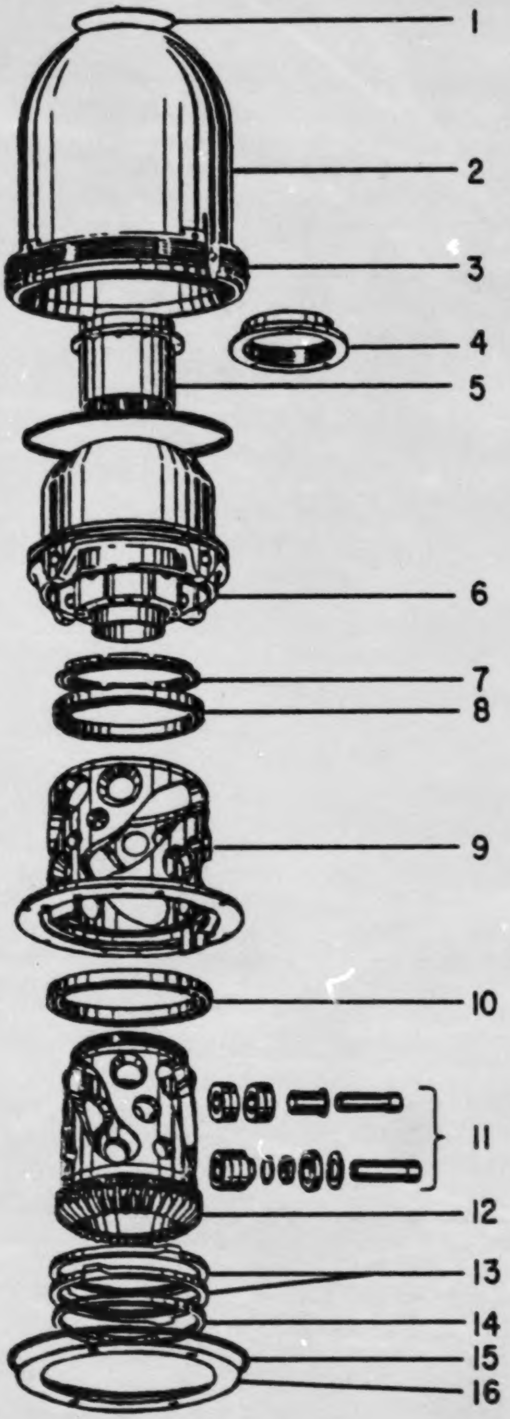

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Figure 12-11.–Dome assembly components.

Nomenclature for figure 12-11.

1. Dome cap O-ring seal.
2. Dome shell.
3. Dome retaining nut.
4. Dome cap bushing.
5. Lever sleeve bushing.
6. Piston assembly.
7. Cam bearing nut.
8. Cam outboard bearing.
9. Stationary cam.
10. Cam inboard bearing.
11. Cam roller assembly.
12. Rotating cam.
13. High- and low-pitch stop rings.
14. Stop ring spacer.
15. Dome to barrel O-ring seal.
16. Gear preload shim.

The piston is machined from an aluminum forging. It provides the mechanism for converting oil pressure into forces which act through the cam assemblies and turn the propeller blades. The piston is balanced separately by drilling metal out of the inboard face of the inner wall. Supplementary units include a ledge (land or groove) on the outer piston wall just outboard of the cam roller shaft bosses. A steel sleeve inside the piston wall contacts the low pitch stop lever assembly seal rings and forms the inner oil seal between the high-pressure and

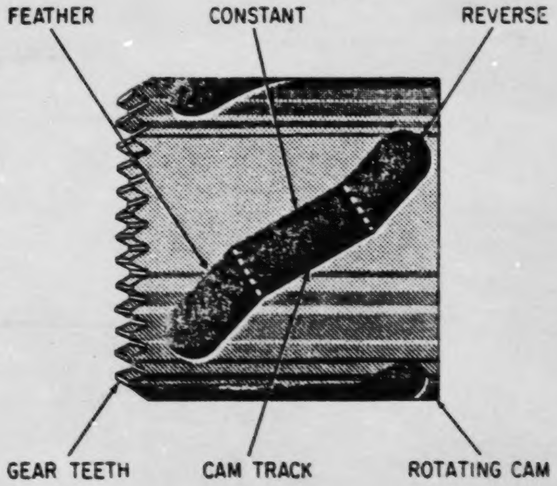

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Figure 12-12.–A three-slope cam track.

low-pressure sides of the piston. Small bleed holes are incorporated in the outer piston wall. These holes allow circulation of a small quantity of warm oil between the inboard and outboard sides of the piston to prevent the oil from congealing during cold weather operation.

Motion of the piston is transmitted to the rotating cam by means of the cam roller assembly.

Two STOP RINGS are provided in the dome assembly to limit travel of the rotating cam and thereby to regulate the feather and reverse blade-angle settings. The stop rings are indexed with the small teeth at the base of the rotating cam. These rings have two lugs which contact the stop lugs machined on the stationary cam. One ring sets the reverse blade angle, and the other sets the feather blade angle. (See figure 12-13.) Propeller blade-angle settings are limited to the predetermined settings of the stop rings.

The DOME SHELL forms the cylinder in which the piston operates. It is fastened to the base of the stationary cam with capscrews. The outboard end of the dome shell incorporates a threaded bushing. This bushing is fitted with a dome cap which is removed to drain oil from the dome and is replaced with a dome lifting handle during removal and installation. A dome retaining nut and dome-barrel seal are supplementary parts of the dome shell.

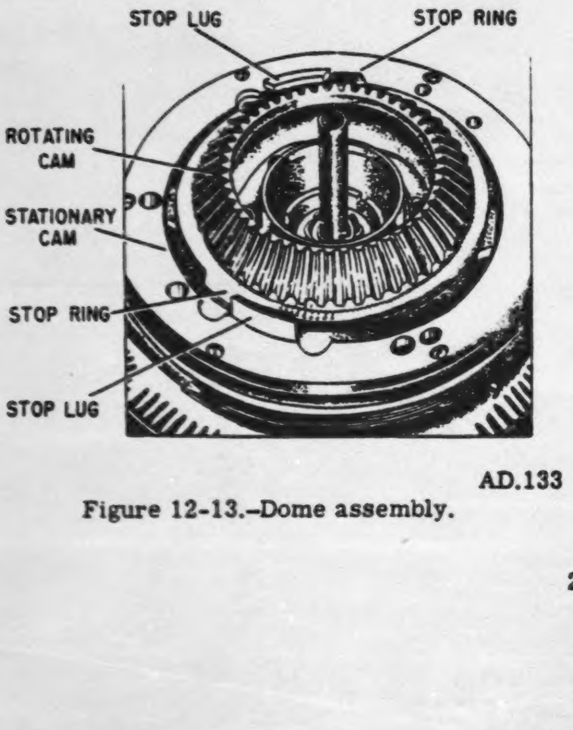

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Figure 12-13.–Dome assembly.

In order to establish the proper gear-meshing load pressure between the rotating cam gear and the blade gear segments, shims are included between the base of the stationary cam and the barrel shelf. These are called GEAR PRELOADING shims and are made of solid brass. They incorporate holes which permit installation of the shims over the stationary cam-locating dowels.

INSTALLATION.–Prior to dome installation each blade should be turned in the hub to either the specified feathered setting or to the proper low pitch setting, and the rotating cam in the dome should be set to the corresponding angle. Although installation at either setting will give the same results, it is recommended that the method of setting the units at the feather angle be used. However, both methods are explained.

To install the dome with the blades set at the FEATHER ANGLE, the blades must be set by aligning the feather angle marked on the blade butt with the barrel index lines. Using the correct tool on the rotating cam gear, turn the cam until the feather stop ring lugs contact the lugs on the base of the stationary cam. This stop ring should, of course, be checked to assure that it is accurately indexed.

Place the required number of shims over the cam-locating dowels. Total shim thickness is marked on the barrel shelf. Do not install the dome-barrel seal at this time.

Screw in the dome lifting handle. Lift the dome and align it with the locating dowels in the barrel. Because of the dowel arrangement, the dome will fit in only one angular position. Just before installing the dome, check that the rotating cam is tight against the stop lug. Then install the dome and tighten it down with the dome retaining nut wrench until it is firmly seated on the barrel shelf. (See figs. 12-14 and 12-15.)

Align the hole in one of the retaining nut lugs with one of the crescent slots in the outboard edge of the barrel; carefully mark this location of the retaining nut. Remove the dome.

Install the dome-barrel seal and again place the dome in position, using the same care as before. Tighten it down until the previously marked aligned holes are lined up.

NOTE: With the dome assembly properly seated in the barrel, the front face of the dome

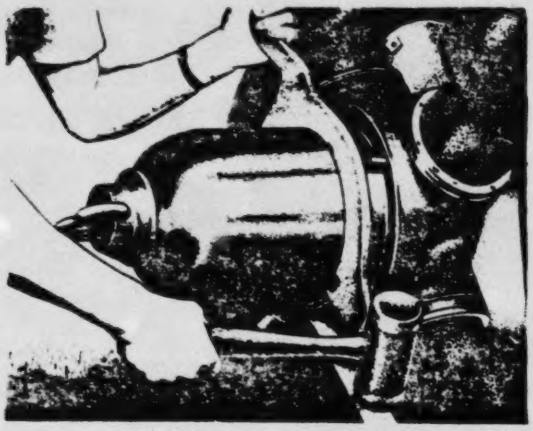

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Figure 12-14.–Installing the dome and engaging the retaining nut thread.

retaining nut will be approximately flush with the outboard edge of the barrel. Failure to properly tighten the dome retaining nut in the hub may result in elongation or failure of the dome shell retaining screws, and oil leakage around the dome retaining nut.

Check the feather angle at the reference station with a protractor and blade template. Blades used on certain installations are aerodynamically balanced, where slight aerodynamic unbalance is critical. Each aerodynamically balanced blade has a correction angle etched on the butt surface. This correction angle should also be marked on the camber surface of the blade. By applying this correction angle to the angle measured at the reference station with the protractor, the true effective aerodynamic angle may be found. The corresponding angles of each blade in a propeller should be within 0.5° of the specified setting, and alike within 0.2° total variation.

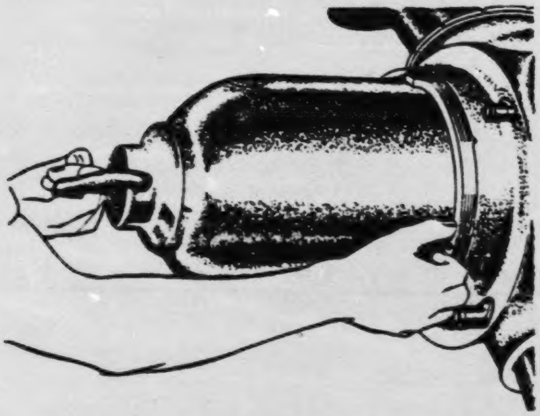

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Figure 12-15.–Tightening the dome retaining nut.

Remove the dome lifting handle and, with a blade turning device, manually turn the blades to low pitch. Again check the setting with a protractor in the manner described above. Insert the dome retaining nut lock screw and safety it with a cotter pin. Install the dome cap seal and dome cap, using the proper torque, and lock in place with a cotter pin (or setscrew and cotter pin).

To install the dome with the blades set at the LOW PITCH ANGLE, set all blades at the proper low pitch (takeoff) angle by means of the blade butt graduations and the barrel index lines. Use the same precautions as previously mentioned. Check to make certain that the propeller piston sleeve has not moved away from the low pitch stop levers. Install the dome onto the hub in the manner as described before.

REMOVAL.–In general, the procedure for removing the dome is the reverse of the installation procedure.

Remove the cotter pin (or setscrew and cotter pin) locking the dome cap, and unscrew the cap. Since the dome is filled with oil, some provision should be made to catch this oil at removal of the dome cap and also when the dome assembly is disconnected from the hub assembly.

Install the dome lifting handle and unscrew the dome retaining nut; then remove the dome (with the stop lever assembly and oil transfer tube in place) by pulling it straight away from the hub, keeping it centered as closely as possible with the axis of the propeller shaft. Be careful not to damage the exposed end of the oil transfer tube during removal of the dome and while setting the dome down on its side after removal.

Governor (Constant Speed Control)

The model 5U18 propeller governor (constant speed control) is covered in this chapter as a typical example.

INSTALLATION.–A general discussion of installation procedure is given here. The appropriate technical publications should be consulted for specific instructions.

If the propeller governor (constant-speed control) is to be installed on a new or overhauled engine, remove the mounting pad cover from the engine nose. Make sure that the shipping gasket included between this cover and the engine pad is also removed. Failure to remove this gasket would affect the flow of engine oil to the control and would cause malfunctioning of the control. When installing the propeller governor constant-speed control, care must be shown in regard to the oil control plugging. The plugging indicates the method by which the governor can be adapted to either clockwise or counterclockwise rotation. For clockwise rotation governors, the pump output check valve is placed in B port and the input sleeve is placed in A port. For counterclockwise rotation governors, the pump output check valve is placed in A port and the input sleeve is placed in B port. Correct rotation can be determined by observing the governor mounting pad on the engine while the engine is being pulled through in the direction of rotation.

Clean the surfaces of the mounting pad and base of the control. Install a new gasket on the mounting pad with the raised portion of the metal screen of the gasket facing up. Install the control on the studs of the mounting pad. The one proper position of the control on the mounting pad is indicated by the shape of the joining surfaces. Make sure that the splines of the control shaft are properly aligned with the internal splines in the engine pad and that the circular boss in the base of the control fits properly into the circular recess in the engine pad. Install the washers and new locknuts and tighten evenly to the proper torque. Lockwire the nuts in pairs.

Connect the auxiliary high-pressure oil line from the auxiliary connecter on the control. Make the electrical connections to the solenoid valve, and other units.

REMOVAL.–The removal of the constant-speed control is the reverse of the installation procedure. If another control is not installed immediately, install a gasket and cover on the mounting pad.

ADJUSTMENTS.–The rpm adjustments of the stepmotor electric head should be made only when the head has been operated away from the maximum and minimum stops. This procedure is recommended because if adjustment is attempted with the control shaft stop lugs in contact with either of the stop screws, the stop bracket assembly may be damaged.

To adjust the rpm on the electric head control, loosen the self-locking nut on the required stop screw and then turn the stop screw in the direction indicated on the stop plate. Each complete turn of the screw is equivalent to approximately 50 rpm.

To adjust the high rpm on the mechanical head control, turn the adjustment screw on the head clockwise to decrease rpm and counterclockwise to increase rpm. One complete turn of the screw is equivalent to approximately 25 rpm. In extreme cases the pulley stop pin may be relocated. A change from one hole to the next is equivalent to approximately 250 rpm. To adjust the low rpm, it is necessary to remove the head, take out the rack assembly, loosen the taper lock screw, and reposition the low rpm adjusting screw in the rack. Each complete turn of the low rpm screw is equivalent to approximately 225 rpm.

BENCH TESTING.–The bench testing procedure for the constant speed control is listed in the test bench operation manual. The correct testing procedure and governor settings are found in the overhaul instructions on the governor.

The safety precautions pertaining to the test bench operation should be complied with. Care should be exercised to prevent excessive pressures from being exerted on the governor during testing. The test bench should be warmed up properly before attempting to test the governor. Figure 12-16 shows a propeller governor test stand.

To check the propeller governor on the test bench, install the governor on the test bench mounting pad. The first check should be the rpm stop settings, and they are as follows:

1. Maximum rpm must be set within 5 rpm of the desired setting.
2. Minimum rpm must be set at 1,200 rpm and within 5 rpm of the desired setting.
3. After making rpm adjustments, the maximum rpm adjustment should be lockwired.
4. Recheck of the maximum and minimum rpm must be within plus or minus 25 rpm of the desired setting.

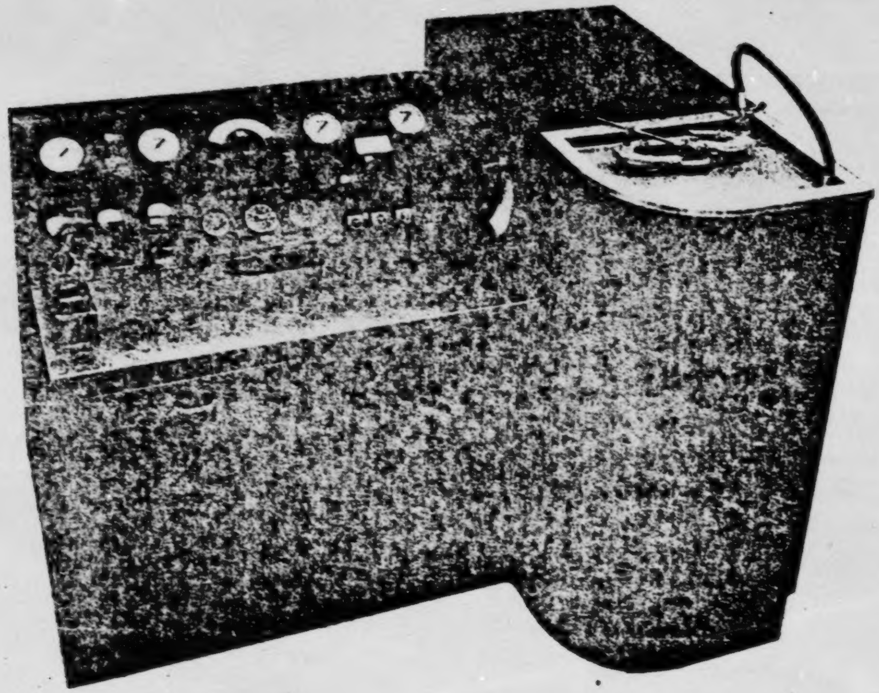

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Figure 12-16.–Propeller governor test stand.

5. Each turn of the adjusting screws on the stepmotor electric head is equivalent to approximately 50 rpm.

The next check is to inspect the governor for external leakage while under pressure of approximately 1,100 psi on output side for at least 1 minute.

Next, check the internal leakage while operating at a back pressure of 150 to 200 psi and a supply pressure of 40 plus or minus 15 psi. If leakage exceeds 1 to 20 quarts per hour, several drive gear shafts and pilot valves should be tested until a satisfactory combination is found. Do not reduce internal leakage below normal minimum, as a sticky pilot valve may result.

When checking the counterbalance rpm, it should be between 2,000 and 2,200 rpm. This rpm can be adjusted by using different balance springs.

The pump capacity test is accomplished by setting the governor head at 1,750 rpm and then adjust the back pressure to 150 psi and the supply pressure to 40 plus or minus 15 psi. The pump capacity must be between 16 and 20 quarts per minute. At 2,800 rpm the pump capacity must not fall below 19 quarts per minute.

The relief valve pressure test is conducted by setting the pressure relief valves at the specified relief setting for the particular model governor. This test must be continued for 1 full minute. On feathering type governors the auxiliary pump inlet fitting must be left open during this test. Relief valves are adjusted by use of shims.

The feathering test is accomplished by setting the governor speed at approximately 2,000 rpm. Supply oil pressure to the connector check valve and check opening pressure of the check valve. A reduction in rpm will indicate correct feathering operation. The auxiliary connector check valve should reseat when pressure is relieved.

For the reversing test, set the governor speed at approximately 2,000 rpm and energize the solenoid valve at 18 volts d.c. An increase in rpm will indicate correct reversing operation. When the solenoid valve is deenergized, the governor should return to its original rpm.

The opening pressure of the pressure cutout switch should be checked. This switch should be checked while installed on the governor, and it should open at 650 psi differential pressure.

The rpm adjustments will be made and the opening pressures of all valves will be adjusted within tolerance while on the test bench.

Blade Repair

The repair of minor injuries to aluminum alloy propeller blades usually consists of dressing down and smoothing out cuts, nicks, and scratches in the blade surface.

Cuts, scars, scratches, surface cracks, nicks, etc., are completely removed, forming a "saucered out" depression smoothly faired into the blade surface. This area must be carefully examined with a three-power magnifying glass to make certain the bottom of the damage has been completely removed. Also, local etching is necessary to be sure that there are no cracks at the bottom of the rework. To avoid removing an excessive amount of metal, this local etching check should be made at intervals during the process of removing the damage. If it is necessary during the rework to remove more metal than is allowed in the repair limits given in the blade dimensional forms of the applicable publications, the propeller should be removed from service and sent to overhaul.

Blades requiring removal of metal which would form a finished depression more than 0.125 inch in depth at its deepest point, 0.375 inch in width, and 1 inch in length, should be sent to overhaul.

NOTE: The information noted here is general in content and does not apply to a specific type aluminum propeller blade. Refer to applicable Operation and Service Instructions for the specific methods to use on a particular model of propeller.

The only acceptable method of removing damage is that by which the metal containing the damage and the adjacent area is removed from the blade with diemakers' rifflers (#8, 10, and 17 "0" cut) and emery cloth. All traces of the damage should be worked from the blade and the resulting depression should be smoothly faired into the surrounding blade surface. Do not attempt to relocate any of the metal in the damaged area by cold-working. The number of repairs in a given area on a blade is not limited provided their locations with respect to one another do not form a continuous line of repairs that would materially weaken the blade structure. For an illustration of minor repairs to the aluminum alloy propeller blade, refer to figure 12-17.

In general, a steel blade having a crack, bend, or bullet hole is cause for the removal of the propeller. No attempt should be made to repair damage of this nature.

The raised edges of cuts, scars, scratches, etc., are dressed off by handstoning. The amount of metal removed should be as small as possible, so that there will be no abrupt change of section

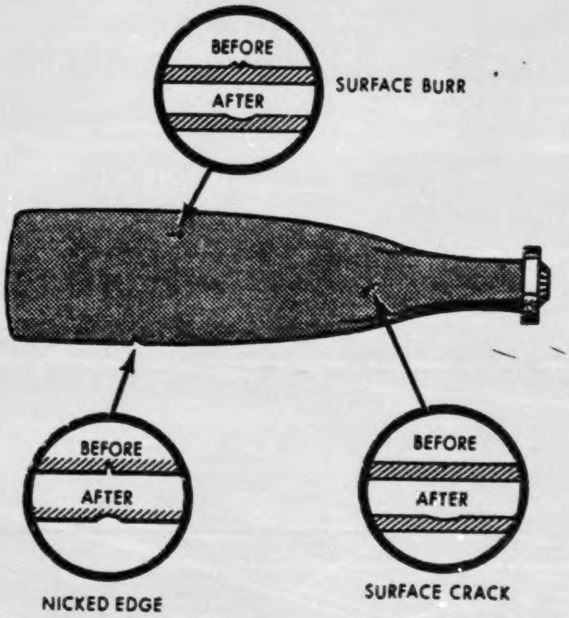

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Figure 12-17.–Before and after rework.

that would cause a stress concentration tending to induce a crack at any point. Under no circumstances should any other metal be removed, nor should other abrasives or tools be used for this purpose.

Small, shallow dents located on the leading or trailing edge, or near the tip, are of no consequence, and therefore do not require repairs. Dents at other locations may be removed, provided that;

1. The necessary tools are available.
2. The strength and performance of the blade are in no way injured.
3. The surface is restored to practically its original shape.

Inspection

Aluminum alloy blades are examined carefully for cracks or other failures, and for bends, nicks, scratches, and corrosion. The application of engine oil to the blades aids in this inspection, and a magnifying glass is also used. If there is any doubt as to the extent of certain types of injuries, local etching should be performed.

The purposes of local etching are:

1. To determine whether visible lines and other marks within small areas of the blade surfaces are actually cracks rather than scratches.
2. To determine, after a minimum removal of metal, if shallow cracks have been removed.
3. To expose small cracks otherwise not apparent.
4. To provide a simple means for accomplishing this work without removing or disassembling the propeller.

The procedures for local etching are:

1. The area of the aluminum alloy blade to be etched should be thoroughly cleaned and dried. Masking tape may be placed around the suspected area to provide protection for adjoining areas.
2. With No. 00 sandpaper, smooth off the area.
3. With a small swab or stick, apply to the suspected area a small quantity of caustic solution.
4. After the area is well darkened, thoroughly wipe it off with a clean cloth DAMPENED with clean water. NOTE: Too much water may remove the solution from a defect and thereby spoil the check.
5. If there is a crack or other defect extending into the metal, it will appear as a dark line or other mark. By further examination through a magnifying glass, small bubbles may be seen forming in the dark line or mark.
6. Removal of these defects is accomplished by means of crocus cloth, fine sandpaper, and fine-cut riffle files. Several applications of the caustic solution may be necessary to determine if the shallow defect has been removed. Immediately upon completion of the final check, all traces of caustic soda must be removed with nitric acid solution, which in turn is thoroughly rinsed off with fresh, clean water. The blade is then dried and coated with clean engine oil.

NOTE: Because they attack metal, the caustic solutions are kept in glass or earthenware containers. If any quantity of solution is spilled, it should be immediately flushed off the surface on which it was spilled (particularly if the surface is metal) with fresh water.

Steel blades may be visually inspected by the magnetic method. As previously noted, covering the blades with oil or rust-preventive compound aids in revealing otherwise obscure defects. The full length of the leading edge (especially near the tip), the full length of the trailing edge, the grooves and shoulders on the shank, and dents and scars should be checked carefully for cracks. Each apparent scratch must be examined carefully through a magnifying glass to determine whether it is a scratch or a crack.

Special equipment is needed to check propellers by the magnetic method. To perform the check, the steel blade or part is mounted in a specially built machine. With a power supply of 2,000 to 3,000 amperes, at 6 volts, the blade is magnetized by rapidly making and breaking the circuit through it 2 or 3 times. A black powder or red mixture of iron filings (Magnaflux) and kerosene is poured over the blade at the same time that it is energized. North and south magnetic poles will be set up on either side of any crack in the metal, and the iron filings will line up in the magnetic field thus created. A black or red line (depending upon the color mixture used) will appear wherever there is a crack in the blade.

Cleaning

All foreign substances must be removed from the propeller surfaces to prevent corrosion and to facilitate inspection.

Steel propeller hubs are cleaned with soap and water, or with an approved cleaning solvent. Tools and abrasives that will scratch or otherwise damage the surface should not be used.

Propeller blades should be cleaned with the same materials used on the hubs. Except in the case of etching and repair, scrapers, power buffers, steel wool, steel brushes, or any other tool or substance that will scratch or otherwise damage the blade must not be used. In special cases, where polish is desired on aluminum alloy blades, an approved metal polish may be used, provided that on completion of the polishing all traces of polish are removed. This is necessary to prevent corrosion by acid contained in the metal polish.

All cleaning substances must be removed immediately upon completion of the cleaning of any propeller part. Soap in any form is removed by thoroughly rinsing with fresh water, after which all surfaces are dried.

Immediately after the inspection and other work following each cleaning or etching, and upon completion of each day's flying, all exposed surfaces of the blades and hubs are coated with clean engine oil or the specified rust-preventive compound to prevent corrosion.

The oil or rust-preventive coating serves two important purposes:

1. It protects the exposed surfaces of the propeller from rust and corrosion.
2. It seeps into cracks that might develop in the blade or hub, making the otherwise obscure cracks stand out.

Propellers on aircraft operating on or near salt water must be treated carefully to prevent corrosion of blades and hub. As soon as possible after a flight near salt water, all traces of salt are removed by thoroughly flushing the propeller with fresh water. All parts are then dried and coated with clean engine oil or rust-preventive compound.

Except during etching, caustic material must not be used on any propeller. The removal of enamel and similar substances from all propellers will be accomplished by the use of suitable solvents, such as approved paint and varnish remover.

Testing

Propeller and propeller accessories must be checked by the Aviation Machinist's Mate R during the ground operational check of the propeller. The propeller controls in the cockpit of a two-engine aircraft may be located as illustrated in figure 12-18.

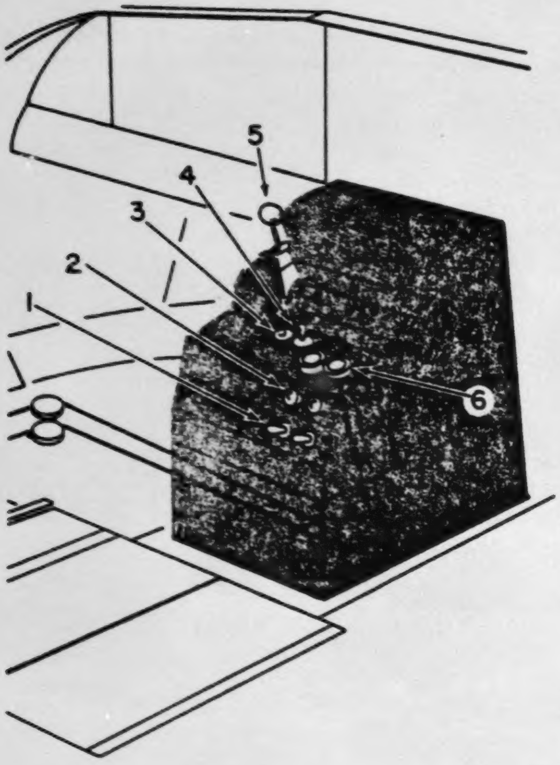
CONSTANT SPEED.–Place the propeller control in FULL INCREASE RPM position. Then set the throttle to obtain maximum cruising rpm. Move the propeller control towards the DECREASE RPM POSITION until a drop of not over 300 rpm is noted. Now slowly increase and decrease the throttle setting and note that the engine rpm remains constant.

MINIMUM GOVERNOR RPM.–Place the propeller control in the INCREASE RPM position. Then set the throttle to obtain approximately 300 rpm above the required low rpm setting. Move the propeller control to the FULL DECREASE RPM position. The engine rpm will decrease to the minimum governing rpm setting of the governor. Next, move the propeller control to the INCREASE RPM position and note that the engine rpm returns to the original setting.

MAXIMUM GOVERNOR RPM.–Place the propeller control in the FULL INCREASE RPM position. Then move the throttle forward until the proper manifold pressure is attained for maximum power. The engine rpm will increase to the maximum rpm setting of the governor and remain constant. NOTE: On some installations it is impossible to obtain the full takeoff rpm in the chocks.

FEATHERING.–With the governor set at maximum rpm, and the engine operating at 1,500 rpm, depress the feather switch button. When the engine speed has dropped to 1,200 rpm, manually pull out the pushbutton switch to its neutral position. The engine should return to 1,500 rpm. This test indicates that the feathering pump is operative and that the feathering line is open.

NOTE: A full feathering test on the ground is generally not required, since the test outlined above shows that the units in the system are



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1. Manual control switches.
2. Indicator lights (maximum increase or decrease rpm).
3. Resynchronize switch button.
4. Master selector switch.
5. Master control lever.
6. Feather switch buttons.

Figure 12-18.—Location of propeller controls.

operative. Completely feathering a propeller on the ground (unless the engine is shut down) presents a serious fire hazard. After performing the feathering test, allow the engine to run at 1,000 rpm for at least 2 minutes so that the oil pump will be able to scavenge the sump preventing the engine from becoming overloaded with oil.

REVERSING AND UNREVERSING.–While the engine is idling, slowly move the reverse throttle lever into the reverse range. As the blades pass through zero pitch, a momentary rpm surge will occur. Proper operation can further be determined by noting increased amperage on ammeters when the auxiliary feathering pump is energized. An increase of approximately 60 amperes per propeller is normal. The duration of the reversing cycle should be 1 to 2 seconds. After the propeller is reversed, apply the specified manifold pressure and note engine rpm. Check the other propellers in the same manner and note the rpm difference between engines. This difference should not exceed 100 rpm with the same manifold pressure setting. (Since these values vary with different engines, check the applicable technical publications for the correct values.)

NOTE: Do not operate the propeller in reverse pitch longer than necessary, as reversed slipstream prevents adequate engine cooling.

Move the reversing lever to the IDLE position. Unreversing should occur at 1,000 to 1,200 rpm. An increase in amperage will again be noted as the auxiliary feathering pump is energized during the unreversing operation.

NOTE: Propellers may be checked individually or simultaneously. After ground operational check, thoroughly inspect the propeller for oil leaks and security. Install spinner nose assembly, if required.

DEICING.—The following procedures apply to the propeller deicer installation on a two-engine aircraft.

1. With the engines running at sufficient rpm to place the generators in service, move the deicer control switch on the copilot's switch console to FAST CYCLE, then to SLOW CYCLE. The amber indicator light beneath the switch should glow with the switch in either position.
2. Close the left propeller deicer circuit breaker and open the right circuit breaker. Check the operation of the timer by noting periodic increase and decrease in the readings of the ammeters during the deicing cycle. The heaters should be on for 20 seconds and off for 60 seconds with the control switch set at FAST CYCLE, and on for 60 seconds and off for 180 seconds at SLOW CYCLE. A deviation of plus or minus 10 percent is allowable for the time intervals.
3. Repeat the check with the right propeller deicer circuit breaker closed and the left circuit breaker open.

4. Close both the left and right propeller deicer circuit breakers and again note the ammeter readings while the deicers are in operation. The circuit should be energized for 40 seconds and off for 40 seconds when the control switch is set at FAST CYCLE, and on for 120 seconds and off for 120 seconds at SLOW CYCLE.

NOTE: During this combined operation, each circuit functions separately, as described in steps 3 and 4 and illustrated in table 12-1.

5. Check that all four-blade heaters on each propeller are operating by noting the total ammeter reading. Approximately 240 amperes should be indicated. If the heater on one blade is inoperative, the total amperage will be approximately 180 amperes. If only one blade heater is operating, approximately 60 amperes will be indicated.

6. If the check in the preciding step indicates that one or more of the blade heaters are inoperative, stop the engines and operate the deicing circuit with AUXILIARY power. Feel the blades to determine which are not being heated.

CAUTION: To avoid overheating the blade heaters during ground checks when the engines are not running, do not operate the deicing system for more than 3 FAST consecutive cycles (generally 20 seconds on and 60 seconds off). Do not exceed 28 volts at the heaters and allow at least 30 minutes between periods of operation. Under no condition should a slower cycle be used during a static ground check.

Propeller accessories should be cleaned with approved solvent prior to visual inspection. Units such as the propeller governor and the feathering pump and motor should be inspected daily for evidence of leakage and for security of mounting. Propeller accessories require no lubrication during routine maintenance.

Table 12-1. —Deicer timer operation.

	Interval No. 1	Interval No. 2	Interval No. 3	Interval No. 4
Both propellers	ON	ON	OFF	OFF
Propeller No. 1	ON	OFF	OFF	OFF
Propeller No. 2	OFF	ON	OFF	OFF

NOTE: FAST CYCLE intervals—20 seconds; SLOW CYCLE intervals—60 seconds.

CHAPTER 14

GROUND HANDLING EQUIPMENT AND PROCEDURES

As naval aviation progressed and new aircraft were developed, new equipment was also developed to service, protect, handle, test, maintain, inspect, and assemble these aircraft. Although Aviation Support Equipment Technicians maintain aviation ground support equipment, they do so at the Intermediate maintenance level only. The user activity is charged with the day-to-day maintenance (daily and preoperational inspections, etc.) of the equipment in their custody. This day-to-day maintenance as well as the operation and servicing of the equipment is assigned to personnel of various aviation ratings. Therefore, the ADR must be familiar with the types, uses, and care of various aircraft ground handling equipment that he will be using in the operation and maintenance of aircraft.

The assignment of aircraft ground handling equipment to an operating squadron depends on the number and types of aircraft assigned and the assigned mission of the squadron. Therefore, the equipment will vary (except the basic equipment) from activity to activity and it would be impossible to cover all of this equipment in one chapter. In this chapter, only the basic equipment that the ADR will be using in the operation and maintenance of aircraft is discussed.

TYPES AND USES

Aircraft ground support equipment is divided into two categories:

1. USN-numbered mobile ground support equipment.
2. Equipment directly related to fulfilling an aircraft maintenance function. This equipment normally does not fulfill any purpose other than to service and maintain aircraft systems or equipment. This is ground support equipment (GSE).

The USN-numbered mobile ground support equipment is normally assigned to the Intermediate maintenance activity and the transportation or public works department of the supporting activity, and furnished to the squadron on a subcustody basis.

NOTE: Only that equipment which is not required (trucks, mobile cranes, etc.) in the day-to-day support of aircraft is maintained by the transportation or public works department. However, due to limitation of space, facilities, personnel, equipment, etc., it may be necessary to have certain Intermediate functions accomplished by public works departments/centers ashore.

GSE is also furnished to the squadrons by the supporting activity on a subcustody basis. The maintenance of the GSE is the responsibility of the supporting activity except for daily and preoperational inspections and servicing, which are the responsibility of the using activity.

MAINTENANCE

The prescribed maintenance requirements for most aircraft ground support equipment are presented to the maintenance man in sets of Daily, Preoperational, and Periodic Maintenance Requirements Cards. NOTE: Daily and preoperational inspections are essentially the same inspection and cover the same items of equipment. Most new equipment will have sets of preoperational cards only. Therefore, the only inspections described in this chapter are the preoperational and periodic. By following the sequence set forth in the card sets, the minimum inspection requirements of the equipment will be satisfied.

Preoperational Inspections

Preoperational inspections are accomplished prior to the first use of the subject equipment for that day. This inspection is basically a combination of requirements for checking equipment that required a daily verification of satisfactory functioning, plus requirements that prescribe searching for and correction of relatively minor problems to prevent their progress to a state that would require major work to remedy.

Other items which require inspection at intervals more frequent than prescribed for periodic inspections are also included on the preoperational inspection and are accomplished along with the preoperational inspection on the day they become due. Preoperational inspections are the only inspections performed by the using activity.

Discrepancies noted on preoperational inspections must be corrected as soon as possible in accordance with local maintenance procedures. If corrective action is beyond the capability of the activity using this equipment, assistance must be obtained from or corrective action taken by the Intermediate level activity.

Periodic Inspections

These are limited overall examinations of the specific item of equipment. They are accomplished by the activity having prime custody of the equipment, usually the Intermediate level activity.

WORKSTANDS AND SERVICING EQUIPMENT

There are various types of workstands and servicing equipment used in the Navy today. An understanding of the uses of each will enable the ADR to perform his task in an easier and safer manner. The following paragraphs describe a few of these items.

MAINTENANCE PLATFORM (B-4A)

The aircraft maintenance platform, Type B-4A, is a hydraulically operated platform and ladder assembly mounted on a caster-equipped base which enables maintenance personnel to work in safety at heights varying from a minimum of 3 feet to a maximum of 7 feet. (See fig. 14-1.)

The B-4A maintenance platform is controllable throughout its platform height range of 3 to 7 feet by means of a hand operated hydraulic pump, mounted on the rear of the work platform. To raise the platform, the pump handle is moved in several back and forward motions until the desired platform height is attained. To lower the platform, the release valve lever on the pump assembly is moved in a counterclockwise direction, which releases the hydraulic pressure.

NOTE: The platform assembly is equipped with two safety lockpins, which must be engaged in position whenever the platform is in use. Remove the lockpins before raising or lowering the platform. Do not operate the pump handle or release valve while standing on the ladder.

MAINTENANCE WORKSTAND (B-1 AND B-2)

The B-1 workstand (view (A), fig. 14-2) consists of a stair structure and work platform mechanically linked together in such a way as to enable both (stairs and platform) to remain level throughout the height range of the stand. Stair support members and handrails are rigged in such a manner to make them self-aligning at all platform levels. Because of the handrails on both the stairs and the work platform, this stand enables personnel to work at various heights in relative safety.

Special provisions are made for extending the B-1 platform height by an additional 4 feet. This is accomplished by placing another stand (view (B), fig. 14-2) into the platform post sockets, which are designed to accommodate this additional structure. The post sockets on the B-1 platform provide for either the attachment of platform handrails or installation of the extra stand for greater height.

The B-2 maintenance stand (view (C), fig. 14-2) is the B-1 stand permanently mounted on a base extension structure of fixed height. The extension base, fabricated of angle iron and steel tubing, is 10 feet in height. This arrangement results in a maintenance stand which has a base structure of fixed height and an upper stair

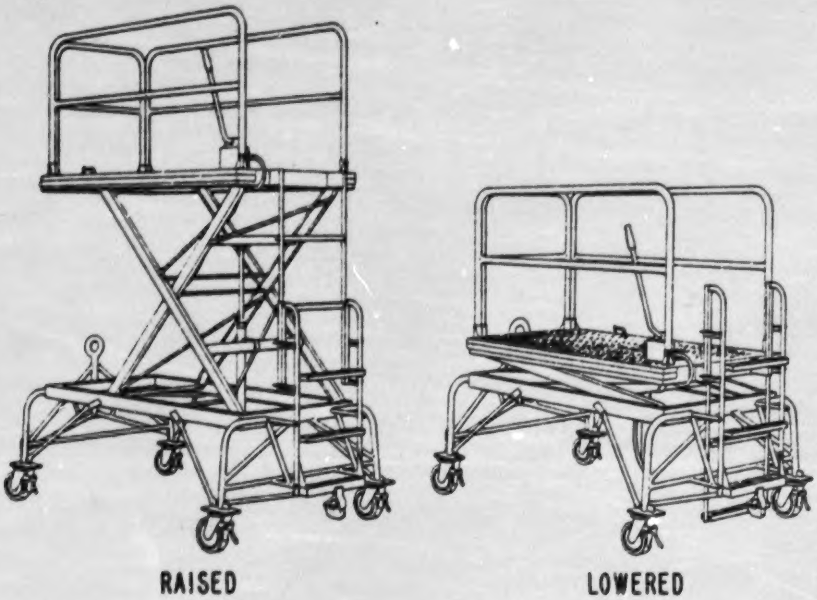

Figure 14-1.–Aircraft maintenance platform, Type B-4A.

structure and work platform which can be hydraulically varied in height.

ENGINE STANDS

There are a number of engine stands used in the Navy, such as the turn-over, fly-away, and the build-up (L) stands.

The turn-over type is used mainly by overhaul activities. It can be adapted to various sections or the complete engine assembly. It can be rotated 360 degrees vertically and horizontally, which allows for positioning the engine at various attitudes for ease of installation or repair of components on the engine.

The fly-away type is usually a very low stand. A cradle for the lower cylinders of the engine to rest on and a post (with adapter) for supporting the propeller shaft are provided on the stand. This stand makes it possible to transport a complete QEC to outlying areas by cargo type aircraft.

The most commonly used engine stand for the reciprocating engine is the "L" stand (fig. 14-3). The name is derived from the shape of the stand. It is utilized in building up and tearing down QEC's. The aircraft engine mount is used to adapt the engine to the stand. On the vertical portion of the stand are two adjustable crossmembers, which can be raised or lowered as required. The legs of the engine mount may be bolted to these members.

There are two work platforms hooked onto the horizontal member of the stand. These platforms enable work to be done on either side of the engine with ease and safety.

AIR CONDITIONERS

One of the most widely used air conditioners is the model NR-3. (See fig. 14-4.) It is a mobile, self-contained ventilating and cooling unit. This air conditioner supplies air within the proper temperature limitations to the cabin conditioning and cooled equipment systems during ground checkout and testing of the aircraft's various systems. The air-conditioning unit is utilized when the aircraft engines are not operating.

The NR-3 is a trailer mounted, Freon-cycle, 120-horsepower, engine driven, mobile air-conditioning unit capable of delivering 180,000 BTU net, or 294,000 BTU gross of conditioned air. This design produces 100 pounds

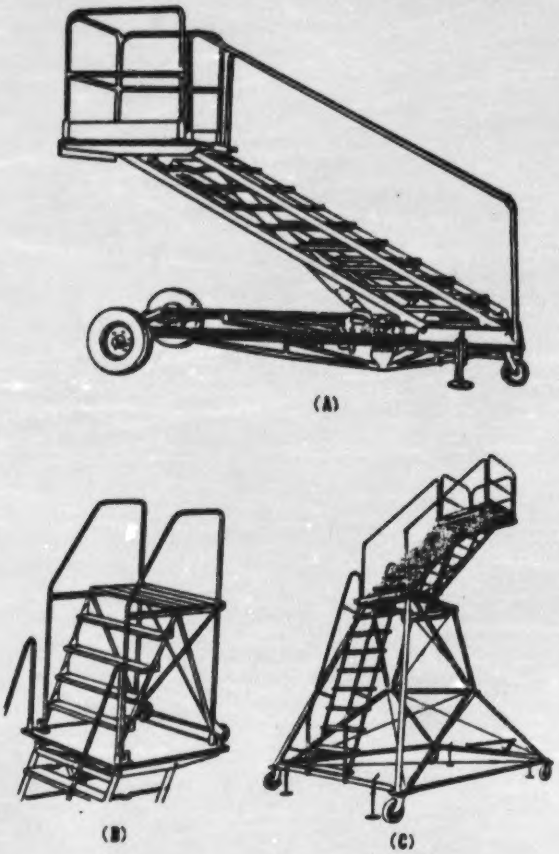

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Figure 14-2.–B-1 and B-2 maintenance workstand.

per minute of cool, moisture free air throughout a range in temperatures from 50° F to 110° F when measured at sea level. The equipment is designed to operate at altitudes up to 5,000 feet above sea level. It is self-sustaining and carries enough fuel and water to provide 4 hours of continuous operation. Provisions for duct storage are provided in the front of the vehicle. A tow bar retainer allows the tow bar to be stored in the vertical position when not in use. The parking brake provides a means of securing the fully loaded unit on grades up to 35 percent.

FLOODLIGHT TRAILERS

The model MC-2 floodlight set is trailer mounted and diesel engine driven. It is designed to furnish highly concentrated illumination upon a centered object, or to illuminate a broad area. There is a great variation in the types of arrangements that can be made in setting up the floodlights. Four mounted stanchions are provided on the top of the trailer on which floodlights can be mounted and rotated 360 degrees in the vertical axis and 230 degrees in the laterial axis, and locked in any position. Also provided with the set are five tripod extensions and five 100-foot, reel-mounted, floodlight power cables. This enables the operator to have four top-mounted floodlights and one tripod mounted with a 100-foot extension power cable. (fig. 14-5) or five floodlights mounted on tripods with 100-foot extension power cables. (See fig. 14-6.) Two or more cables can be interconnected if required.

Flexibility and latitude in the utilization of the floodlight set for illumination are unlimited. The short time factor involved in setting up the floodlight set for operation and unrestricted mobility offers a high asset to any operational requirement.

NOTE: Before towing the floodlight set, insure that all gear is properly stored. The operator of the towing vehicle should familiarize himself with restrictions on turning radius and road clearances of the trailer before towing.

TOWING, STARTING, AND HOISTING EQUIPMENT

Towing, starting, and hoisting equipment are important to the ADR in that he must use all of these items in the performance of his duties. Being able to select the right piece of equipment for the job will make the job safer and easier.

The tow tractor is the only means of propulsion for a majority of aircraft when on the ground and the engines not running. The tractor's maneuverability depends on its size and turning radius. Another factor is the drawbar pull, which is the force the tractor can exert. The drawbar pull is rated maximum for dry concrete surfaces.

Starting units in use today vary with the type aircraft. The NC-5, which supplies d-c power for starting plus a-c and d-c power for servicing purposes, is discussed in this section.

There are many types of hoisting equipment, each having its own specific design. When

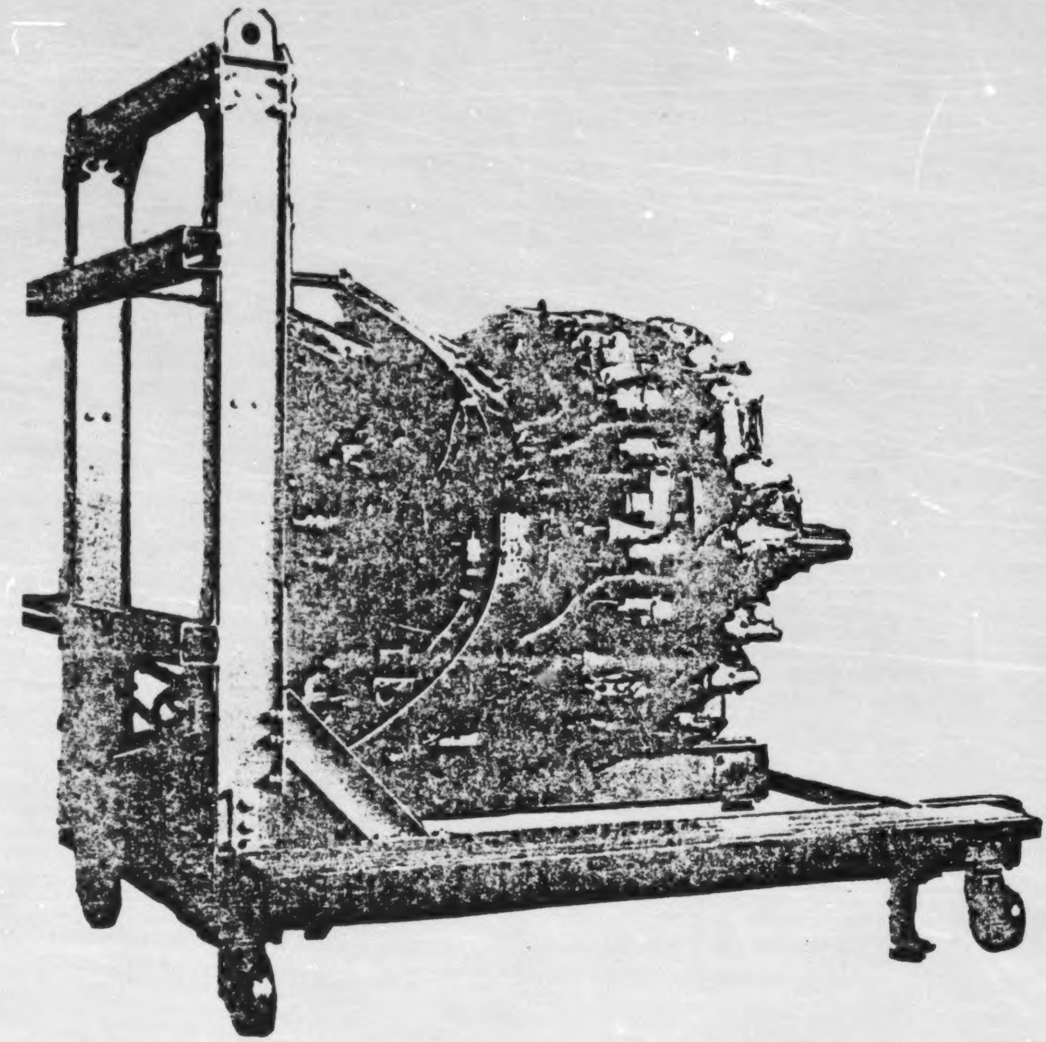

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Figure 14-3.–Reciprocating engine stand.

selecting hoisting equipment, keep in mind the following factors–weight to be lifted, height it must be raised, distance to be moved, and the angle or attitude of the final positioning.

TA-18 TOW TRACTOR

The TA-18 (fig. 14-7) is designed to tow large aircraft, such as patrol type, on various types of surfaces in the various kinds of inclement weather, from a minus 25°F to plus 125 125° F. It is powered by a V-8 gasoline engine and equipped with a 6-speed transmission, 1 reverse and 5 forward, and 4-wheel drive. It weighs 25,000 pounds and has a drawbar pull rating of 18,000 pounds. Due to the size of the TA-18, the steering is power assisted and has a turning radius of 24 feet 10 inches. The service brakes are vacuum assisted.

CAUTION: The size of the TA-18 Tractor limits the view of the operator. When operating near an aircraft, another man should be used

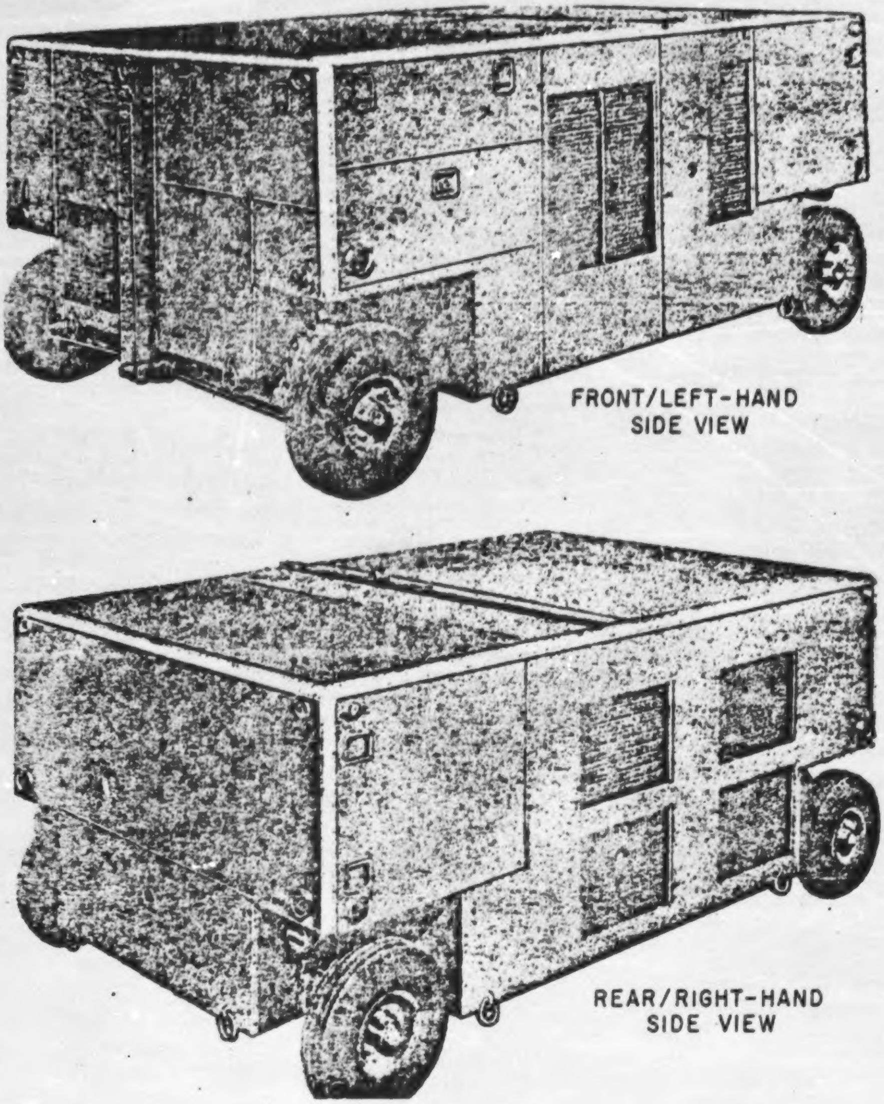

Figure 14-4.–NR-3 mobile air conditioner.

to direct the operator to prevent damage to aircraft or possible injury to personnel.

TA-75 TOW TRACTOR

The TA-75 (fig. 14-8) is designed to tow all aircraft, on shore, up to 75,000 pounds gross weight. It is powered by a Chrysler industrial six-cylinder engine. It is equipped with an automatic transmission and power assisted steering, with a turning radius of 10 feet. The TA-75 weights 10,500 pounds and has a drawbar pull rating of 7,500 pounds. The service brakes are the standard hydraulic internal expanding type.

A gas turbine compressor may be mounted at the rear of the tractor to provide pneumatic power in the form of compressed air for

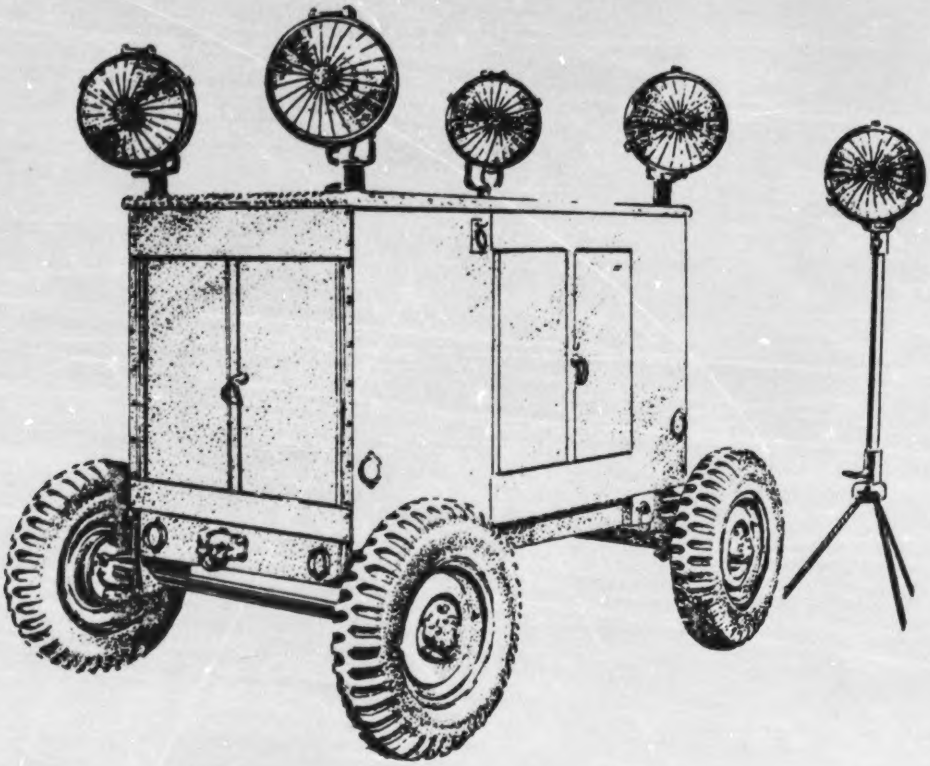

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Figure 14-5.–MC-2 floodlight set.

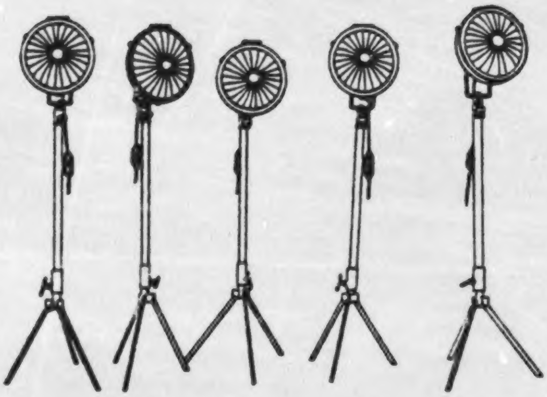

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Figure 14-6.–Floodlights mounted on tripods.

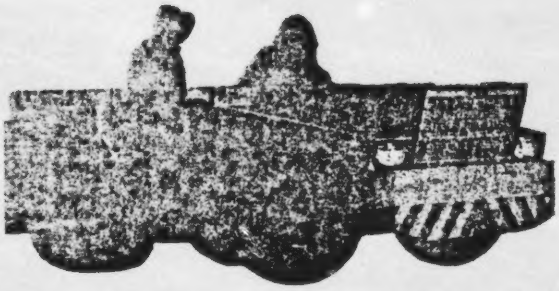

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Figure 14-7.–TA-18 tow tractor.

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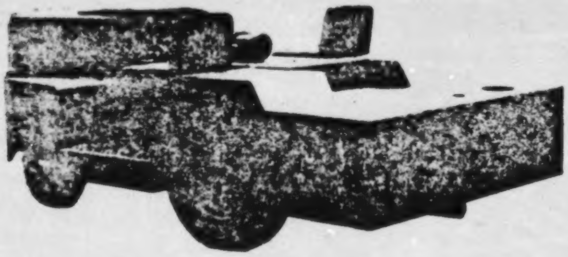

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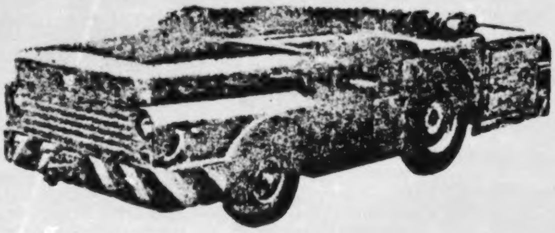
Figure 14-8.–TA-75 tow tractor.



AB.255
Figure 14-9.–MD-3 tow tractor.

operation of large class pneumatic equipment, such as aircraft main engine starters, air-conditioning systems, and other type consumers of compressed air.

MD-3 TOW TRACTOR

The MD-3 (fig. 14-9) is primarily designed for use aboard carriers. The overall heights is 36 inches, which enables it to be operated on crowded hangar and flight decks by driving under the winds of parked aircraft. The MD-3 can tow aircraft on various surfaces in the various kinds of inclement weather that may be experienced through a temperature range of minus 25° F to plus 125° F. It weighs 12,000 pounds and has a drawbar pull rating of 8,500 pounds.

A gas turbine compressor, mounted at the rear of the tractor, provides pneumatic power in the form of compressed air for the operation of large class pneumatic equipment, such as aircraft main engine starters, air-conditioning systems, and other type consumers of compressed air.

The main powerplant of the tractor is an inline horizontal four-stroke cycle, internal diesel combustion type engine. The steering system is hydraulically assisted, with a turning radius of 11 feet, and the service brakes are assisted by compressed air.

CAUTION: Tractors equipped with gas turbine compressors must have a minimum distance of 8 feet maintained between the exhaust outlet and aircraft when the gas turbine compressor is in use. For those equipped with 85 series turbines, with upward exhaust ports, a minimum of 6 feet must be maintained. It is emphasized that these are minimum distances. Factors such as length of time the unit is in use and the effect on direction and concentration of exhaust resulting from nearby jet/prop plast and local wind require care in aircraft spotting and handling.

The catastrophe aboard the ENTERPRISE on 14 January 1969 may have been avoided if the aforementioned had been adhered to. Preliminary indications are that the exhaust from a gas turbine compressor ignited a Zuni rocket warhead mounted on an F-4J, initiating the subsequent explosions and fires.

Attention must also be paid to the positioning of these tractors equipped with gas turbine compressors so that the turbine wheel plane of roation presents a minimum hazard to personnel and equipment in the event of turbine disintegration.

STARTING UNITS (NC-5)

Starting equipment will vary with the type aircraft to be started. The Waukesha, NC-5, NC-6, NC-12, and the gas turbine compressor are various types of starting equipment designed for a specific starting system. The NC-5 is one of the most widely used units and is discussed in the following paragraphs.

The NC-5 unit is self-propelled and may be driven from place to place in the same manner as any other motor vehicle. (See fig. 14-10.) It has provisions for delivering three different kinds of power, each through a separate cable. It will deliver d-c power for servicing purposes. It will also deliver sufficient d-c power for starting jet engines, but only for 1 minute at a time. Bother servicing and starting power are taken from the same generator; however, this generator will deliver only one type of power at a time.

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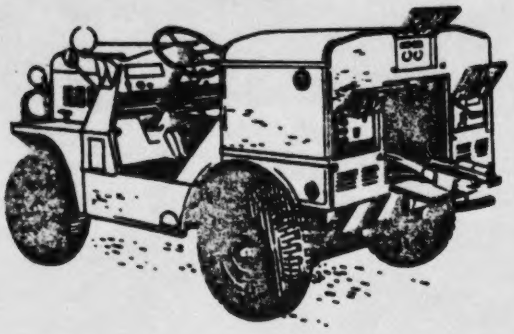

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Figure 14-10.–NC-5 starting unit.

In addition to d-c servicing and starting power, the NC-5 will deliver a-c power for servicing a-c equipment in the aircraft and rectified d-c power for servicing during the starting cycle.

The NC-5 being a self-propelled unit, should be treated with as much care as an automobile, Servicing materials and procedures are similar to those for two tractors. The NC-5 should be operated only by a qualified and authorized operator.

CRANES

There are various types of cranes in use in the Navy. They are designed to lift small loads to loads of several thousand pounds, and under various conditions, such as the angle or attitude from which the item must be approached. Due to the large variety of cranes, only the NS-50, MB-1A, and the M-65 cranes are discussed in the following paragraphs.

When selecting a crane for use, keep in mind the factors mentioned earlier–weight to be lifted, height it must be raised, distance to be moved, the angle or attitude of the final positioning.

The maximum performance of a crane dedepends on the ability of the operator to properly operate the crane. Therefore the operator must be thoroughly familiar with the contents of the applicable technical manual before attempting to operate a crane.

NS-50 Crane

The NS-50 mobile crane (fig. 14-11) is designed primarily to lift and carry aircraft on the flight deck of an aircraft carrier. The crane is equally suitable for similar duty on shore stations for both aircraft landing area and paved or unpaved operational areas.

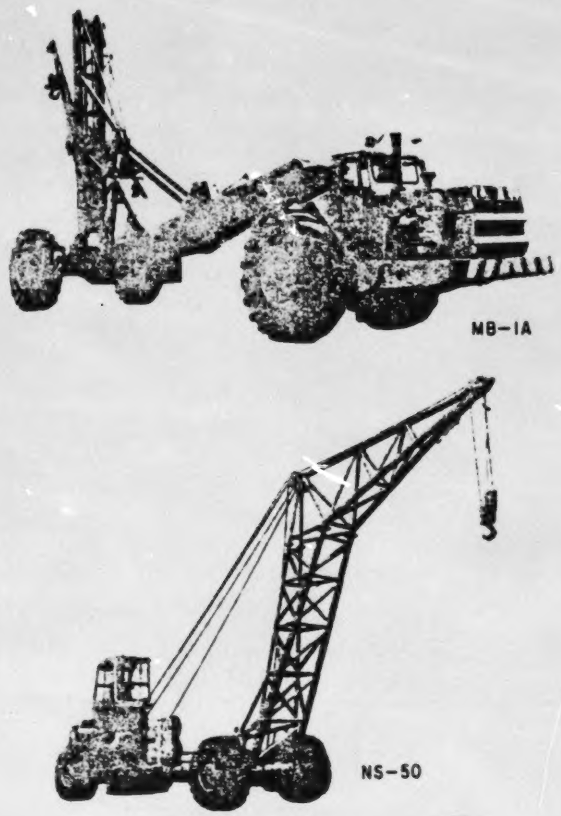

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Figure 14-11.–Mobile cranes.

This crane, a self-propelled vehicle, is mounted on four electrically powered wheels. Heavy-duty d-c electric traction motors and gear reduction units built within the wheel rims provide motive power for the crane. Each wheel motor is equipped with multiple disc type spring-loaded brakes for emergency stops and parking. Whenever the electrical power is secured, the brakes are set by spring force.

All normal operations required for maneuverability of the crane are managed from the operator's station. A remote control panel on the rear of the crane permits control of the hook and boom at a point near the load.

The crane is 40 feet long without the boom. With the boom extended 23 feet, the overall length is 64 feet 9 inches. The overall height is 33 feet. The gross weight of the crane is 72,300 pounds.

The crane is capable of lifting 50,000 pounds when its boom is positioned anywhere between its minimum and 23-foot outreach. The crane is capable of exerting a drawbar pull of 42,000 pounds for towing operations.

MB-1A Crane

The MB-1A mobile crane (fig. 14-11) is designed primarily for lifting, maneuvering, and removing crashed aircraft from air station runways and surrounding areas. The MB-1A is made up of a 2-wheel vehicle (prime mover) attached to a 2-wheel crane.

The prime mover is powered by a diesel engine driven through a twin-disc clutch, a 5-speed transmission, a high/low speed auxiliary transmission, and a torque-proportioning differential. The auxiliary transmission in combination with the 5-speed transmission results in 10 speeds forward and 2 speeds in reverse. The wheels of the crane are not powered.

An a-c generator, driven from the engine flywheel, supplies current for powering the hook, jib, boom, and the steering motors. These motors are controlled by fingertip switches located at the operator's station. A remote control box is provided for controlling the hook, jib, and boom motors from a position near the point of pickup.

The crane is 41 feet 7 inches high with the boom retracted. It is 59 feet 9 inches long with the boom retracted and 84 feet long when the boom is extended to its maximum. The gross weight is approximately 100,000 pounds.

The crane is capable of lifting 80,000 pounds when its boom is positioned anywhere between 7 feet and 17 feet behind the centerline of the wheels.

M-65 Crane

The M-65 crane (fig. 14-12) is designed for off the road operation in rough terrain. It is powered by a three-cylinder, two-cycle diesel engine, with 4-wheel drive transmission.

It is equipped with a 3-ton capacity boom crane and 75,000 foot-pound line power winch for lifting, towing, and related operations.

The crane is 8 feet 8 inches high with the boom retracted. It is 17 feet 8 inches long with boom retracted and 24 feet 4 inches long when boom is extended to its maximum. The maximum elevation of the boom is 75 degrees. The gross weight is approximately 21,000 pounds.

The crane is equipped with hydraulic assisted front and rear wheel steering. The turning radius for front wheel only is 30 feet, with front and rear wheel steering, 17 feet.

AIRCRAFT HOISTING

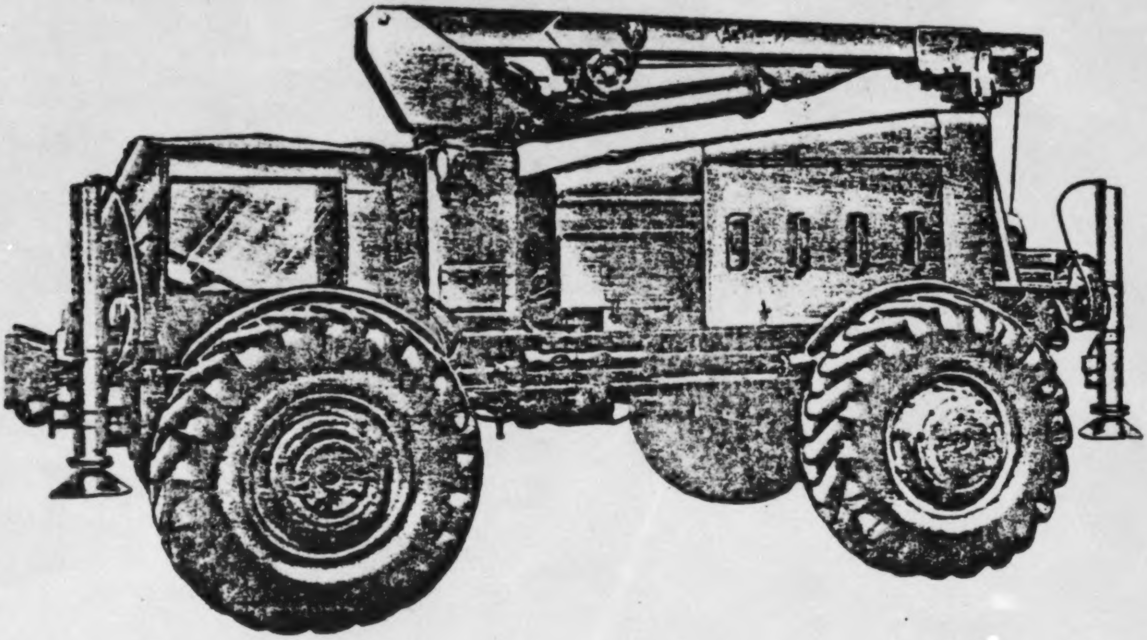
Before hoisting an aircraft the sling should be inspected for cable fraying, security of all attach fittings, and proper attachment to the aircraft or components. The sling assembly is used to hoist the entire aircraft in various stages of disassembly as well as the complete aircraft.

On the SP-2H aircraft there are four fittings attached prior to attaching the sling. Two fittings are attached to the top of the fuselage, just aft of the cockpit, and one to each wing, top aft of the engine nacelle. After installation of the fittings a three-cable sling is attached, as shown in figure 14-13. The cables are attached by means of shackles and bolts. All movable points of the sling, such as shackles and bolts, should be lubricated prior to use to prevent a sudden jerk during hoisting, due to a stuck shackle or bolt.

NOTE: Prior to hoisting a complete aircraft, insure that the aircraft gross weight does not exceed the designed landing gross weight. Prior to hoisting the complete aircraft or any of the major assemblies, attach stead lines at convenient points to prevent oscillation. At no time should personnel be under the aircraft or major assemblies during hoisting operations.

PNEUMATIC LIFTING BAG

The pneumatic bag (fig. 14-14) is a device which lifts crippled aircraft from terrain where it is impractical or impossible to use standard aircraft jacks. The pneumatic bag has a lifting capacity of 12 tons and inflates to a height of 90 inches. Internal bulkheads maintain the "box shape" of the pneumatic bag. The outer material



AD.148

Figure 14-12.–M-65 crane.

is one-ply nylon fabric specially treated for extreme atmospheric temperatures. The inlet valve is located on the front upper left-hand corner (refer to fig. 14-14), when in deflated state. An air hose assembly is attached to this valve, and air is pumped in until the required height of the pneumatic bag is obtained. On the lower left-hand corner of the rear side and on the upper right-hand corner of the front side of the bag are two outlet assemblies. These assemblies allow the penumatic bag to be deflated.

The pneumatic bag is stored in a protective tarpaulin assembly. After removing the pneumatic bag from the tarpaulin protective assembly, the tarpaulin is placed under the area desired to be lifted. The penumatic bag is then placed on the tarpaulin under the area to be lifted.

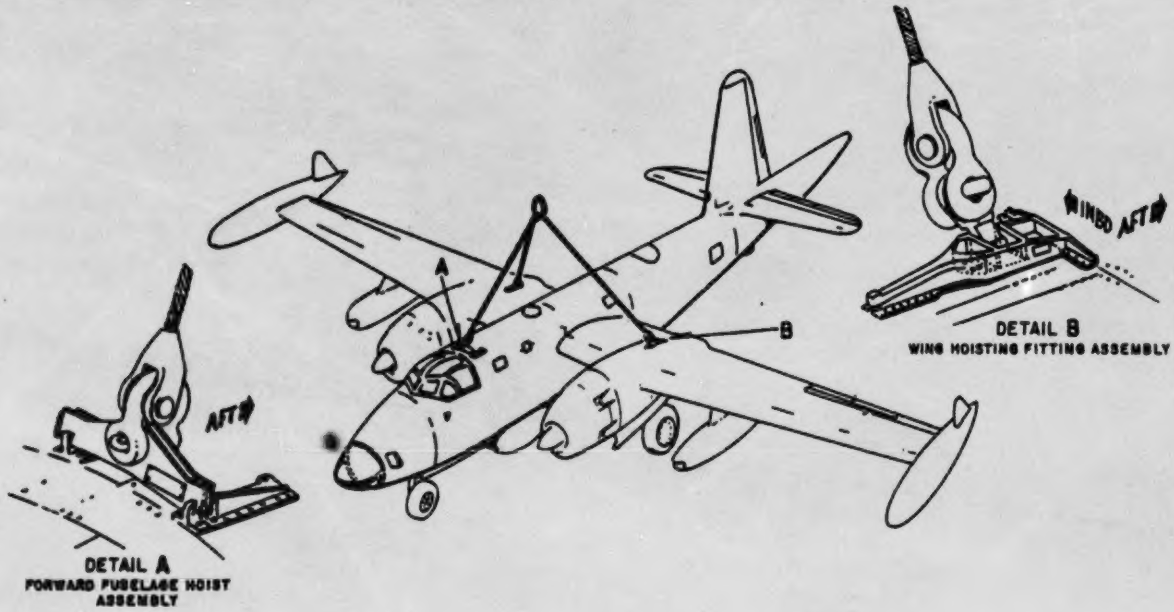
CAUTION: Insure that the ground and underside of the aircraft have no sharp projections or roughness which could puncture or tear the pneumatic bag. When such hazards are unavoidable, they should be carefully padded.

Caution should also be taken to prevent the aircraft from nosing over or shifting and yet allowing upward movement.

The bag is inflated by attaching an air hose to the inlet valve and slowly pumping in air until the desired height or maximum bag pressure is obtained. The maximum bag pressure is 3.5 psi. After the repair is accomplished, open the outlet assemblies and allow the bag to deflate. NavAir 19-1-59, Operation and Service Instructions, should be referred to for more detailed operation instructions.

SAFETY

Operational readiness of a maximum number of aircraft is necessary if naval aviation is to successfully perform its mission. Keeping its aircraft in top operating condition is the principal function of naval aviation maintenance


A
B
AFT
INBD AFT
DETAIL A
FORWARD FUSELAGE HOIST ASSEMBLY
DETAIL B
WING HOISTING FITTING ASSEMBLY

AD.149

Figure 14-13.–Aircraft hoisting.

personnel. It is essential that maintenance work be performed with a minimum of injury to personnel and damage to equipment and aircraft.

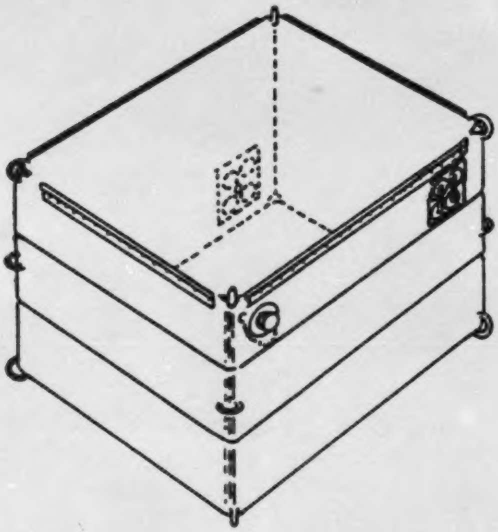


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Figure 14-14.–Pneumatic lifting bag.

The concept of aircraft maintenance safety should extend beyond concern for injury to personnel and damage to equipment and aircraft. Safe work habits go hand-in-hand with flying safety. Tools left in aircraft, improper torquing of fasteners, poor housekeeping around aircraft, and improper and careless operation of ground support equipment can cause conditions which may claim the lives of flying personnel as well as cause strike damage to aircraft. Safety on the ground is equally as important as safety in the air.

Technical knowledge plays a large part in a good maintenance program. The complexity of our modern equipment demands the attention of well-informed and expert maintenance personnel; otherwise, our weapons systems cannot be operated and maintained. Technical knowledge is a function of education and training which, incidentally, does not end with graduation from Class A school. Graduation is only the beginning. An ADR worthy of the rating is continually training and learning through self-study and application, and through a personal desire for proficiency and self-betterment. But technical knowledge by itself is not sufficient unless it is coupled with an old-fashioned and craftmanship in doing any job well. The ADR who wishes to contribute to safety and reliability improvement must know his job and must develop professional pride in the quality of his work.

It is a continuing duty of every person connected with aircraft maintenance to try to discover and eliminate unsafe work practices. Accidents which are caused by such practices may not take place until a much later date and their severity cannot be predicted.

CHAPTER 15

LINE OPERATIONS AND MAINTENANCE

Line operations and maintenance is one of the most important responsibilities of the ADR. The term line operations and maintenance is defined as the process involved to insure that operational aircraft (including guided missiles), aircraft equipment, and aircraft support equipment are ready and safe for the type of flight or operation for which they are scheduled. This work is performed on or in aircraft or equipment located on a flight line, flight deck, or other places normally used by the activity to park aircraft. It is usually performed prior to or between scheduled flights, without removal of the aircraft from the flight schedule.

Line operations and maintenance includes servicing; daily, preflight, and postflight inspections; ground tests; troubleshooting; correction of minor discrepancies; compliance with applicable instructions for adjustments and replacement of parts (which do not require removal of units, assemblies, and subassemblies); and the security and proper ground handling of aircraft and associated support equipment.

As previously stated, line operations and maintenance is one of the most important responsibilities of the ADR. It is essential that he know the engine as thoroughly as possible. He must have a working knowledge of the complete aircraft to which he is assigned and he must be familiar with and observe all safety precautions.

SAFETY

Operational readiness of a maximum number of aircraft is necessary if naval aviation is to successfully perform its mission. Keeping its aircraft in top operating condition is the principal function of naval aviation maintenance personnel, and an essential objective should be to perform maintenance work without injury to personnel and without damage to equipment or aircraft. Therefore, the one thing that must be strongly stressed at all times is SAFETY FIRST.

When working on the line around propeller-driven aircraft, the first general precaution that you must observe is to BEWARE OF PROPELLERS. When you see a propeller, let it be a constant reminder to "Stay Clear!" In general, do not cross in front of moving propellers, as whirling propellers are not easily seen. The area around an aircraft must be kept clear of loose gear and debris.

Another constant danger on the line is fire. Because of the large quantities of easily ignited fuel, carelessness with gasoline, static electricity, or the improper handling of tools may cause a spark and start a serious fire.

The most common fire prevention rules are as follows:

1. Covered metal containers must be provided and used for storing supplies of clean rags, waste, and other combustible materials for immediate use.
2. All used waste, rags, and other combustible material must be deposited in plainly marked covered metal containers.
3. Containers, plainly identified and kept separate from those in item 2 above, must be used for oil and paint-soaked materials.
4. Disposition of these containers must be made with such frequency and in such a way that they will not become a fire hazard.
5. No smoking and no open flames are permitted within 50 feet of parked aircraft, hangars, shops, or other buildings in which highly flammable materials are stored or being used.

6. Grounds, particularly around buildings and aircraft, must be kept free of fire hazards, such as trash and dried vegetation.

7. Suitable fire lanes for passage of fire-fighting equipment should be designated, marked, and kept clear.

POWER-OPERATED EQUIPMENT

As naval aviation progressed and aircraft became larger and seemingly more complex, provisions were made to assist in the operation of such equipment as control surfaces, speed brakes, canopies, and landing gear doors. Also, seat ejection mechanisms were installed in most aircraft. Although these were designed with safety in mind, they broaden the danger area for ground personnel. Some of the safety precautions that must be observed when working on or around aircraft are discussed in the following paragraphs.

Ejection Seats and Canopies

Normally, the Aviation Machinist's Mate R will not come in contact with ejection seats, as they are found in jet engine aircraft; however, a word of caution is mentioned here. If the reciprocating engine mechanic has an occasion to ride the brakes or aid in the performance of work on an aircraft with this type of equipment installed, he should keep his hands off of red-flagged lanyards and other units painted red in the cockpit. All safety precautions must be strictly observed when working around aircraft equipped with an ejection seat. These safety precautions cannot be overemphasized, as accidental actuation of the firing mechanism can result in death or serious injury to anyone in the cockpit area.

Each ejection seat has several ground lock safety pins, the exact number depending upon the type of seat. These safety pins are provided on red-flagged lanyards for use at every point of potential danger. They must be installed whenever the aircraft is on the ground or deck, and must never be removed until the aircraft is ready for flight.

The following general safety precautions should always be kept in mind:

1. Ejection seats must be treated with the same respect as a loaded gun.

2. Always consider an ejection seat as loaded and armed.

3. Before entering a cockpit, be checked out on the location of the ejection seat safety pins and be certain they are installed. If you are not checked out, stay out of the cockpit.

4. Only authorized personnel may work on ejection seats and components and only in an authorized area.

The canopies of several modern day reciprocating engine aircraft are power operated as are all jet engine aircraft. These canopies are so designed that they can be opened in an emergency.

Aircraft manufacturers use various methods of actuating the canopy. Normal opening and closing may be accomplished pneumatically (with compressed air), electrically, hydraulically, or manually. In most aircraft, two methods are provided; thus, if one system fails, the other may be used. The closing operation of the canopy can be dangerous if care is not taken. Power operated canopies can cut off fingers and break bones.

Movable Surfaces

Movable surfaces such as flight control surfaces, speed brakes, and landing gear doors constitute a major hazard to flight line personnel. These units are normally operated during ground operations and maintenance. Therefore, care should be taken to insure that all personnel and equipment are clear of the area before operating any movable surface.

The General Information and Servicing section of each Maintenance Instructions Manual contains specific information concerning the various movable surface hazards and specifies the safety locks which must be used. Personnel involved with line operations and maintenance should pay particular attention to this information since some of these units move extremely fast and with terrific power.

TAXIING, TOWING, AND JACKING

No one is permitted to taxi an aircraft except such persons as are authorized to fly it and those who have been specifically designated and authorized by the commanding officer.

All taxiing must be done at safe, authorized speeds and in a manner appropriate to the type of aircraft being taxied, care being taken that the path ahead is clear of other aircraft, equipment, and obstructions.

Sufficient ground control personnel must be available to provide for the safe taxiing or aircraft in the vicinity of obstructions of other aircraft.

Only approved standard aircraft taxi signals are to be used. The approved fixed wing and helicopter taxi signals are illustrated in the Airman Manual, NavPers 10307-C, chapter 12.

Aircraft are usually moved about on the line by towing. After the proper authorization to move an aircraft has been obtained, an authorized and qualified operator must be in the aircraft, ready to operate the aircraft brakes when necessary.

Towing couplings should be thoroughly inspected prior to towing. Only approved attachment devices are to be used. Attachments are made secure to couplings on the aircraft provided for this purpose.

Only qualified personnel are permitted to move or operate towing equipment and attachments. It must be made certain that all is clear and in readiness prior to operation of equipment.

Towing speed should never exceed 5 miles per hour. Sudden starts or stops must be avoided. Extreme caution must be exercised when towing an aircraft over rough or muddy ground, or into or through a congested area.

When towing an aircraft near hangars or obstructions, a wing walker should be stationed at each wingtip to insure adequate clearances. At night the wing walker must carry a flashlight or luminescent wand.

The ADR must be familiar with the jacking of aircraft and the safety precautions to be observed. As jacking procedures vary for different types of aircraft, only the general jacking procedures and safety precautions are discussed here. Consult the applicable maintenance instructions manual for the specific procedures to be used for specific aircraft.

When an aircraft is to be jacked, it must be located in a level position, well protected from the wind. The aircraft should be moved into the hangar if possible. The jack pads should be installed at the jacking points. The jacking points are usually located in relation to the aircraft's center of gravity so that the aircraft will be balanced on the jacks. For some aircraft, however, it may be necessary to add weight to the tail or to the nose to achieve a safe balance. Sandbags or shotbags are usually used for this purpose.

The jacks used for jacking the aircraft, whether for jacking the complete aircraft or just a wheel, must be in good working condition. A leaking or damaged jack should never be used and its maximum capacity must never be exceeded. The area around the aircraft should be roped off while the aircraft is on jacks. Climbing on the aircraft should be held to a minimum, and no violent movements should be made by persons who are required to go aboard. Any cradles or necessary supports designed for that purpose should be placed under the fuselage or wings of the aircraft at the earliest possible time, particularly if the aircraft is to remain jacked for any length of time.

When only a wheel is to be raised, for instance, when changing a tire or greasing the wheel bearings, all remaining wheels must be chocked both fore and aft. If the aircraft is equipped with a tailwheel, it must be locked. The wheel to be worked on should be raised only high enough to clear the deck and no more.

COMPRESSED AND LIQUID GASES

Fluids under pressure are a potential hazard on the flight line unless strict safety precautions are observed. Some of the pressurized fluids with which the ADR should be familiar are in the form of a gas; others are in liquid form. Some of these gases and liquids are discussed in the following paragraphs.

Carbon Dioxide

Carbon dioxide (CO_2) is a colorless, odorless gas. It can be condensed into a colorless liquid and stored as such, under pressure, in cylinders. When the cylinder valve is opened, gaseous CO_2 escapes and, due to the rapid drop in pressure and temperature, forms carbon dioxide snow. This snow, when compressed into blocks or cubes is what we know as "dry ice."

Because it will neither support combustion nor form explosive mixtures, CO_2 is one of the chief fire-extinguishing agents in use today. It is also used for inflatable gear, such as liferafts and lifevests. However, there are some safety precautions which you must observe. Do not enter an area or compartment containing hazardous amounts of carbon dioxide without being equipped with a breathing mask and an independent supply of oxygen. Although carbon dioxide is not toxic, the obvious fact is that, poisonous or not, the more gas that is present, the less breathable oxygen there will be present. Men going into these places run the risk of smothering to death.

Gaseous Oxygen

Gaseous oxygen is a colorless, odorless gas which does not burn, but it supports the combustion of other things. Even steel will burn in pure oxygen.

Gaseous oxygen is normally contained in cylinders and identified as one of two types: (1) aviators' breathing oxygen or (2) industrial or technical oxygen. There is no difference in the purity of the oxygen itself in these two types. The only difference is in the moisture content of the cylinders. Cylinders containing aviators' breathing oxygen have been dried inside, before being charged, to prevent failure of breathing apparatus due to the formation of ice under high altitude freezing conditions.

To simplify the supply system, aviators' breathing oxygen is the only kind stocked by ships and is used on shipboard for welding and cutting operations as well as for breathing purposes.

Industrial or technical oxygen, supplied for nonshipboard use in welding and cutting operations, can be and is used for breathing purposes, other than aviation, because its purity is identical with that of aviators' breathing oxygen, and freezing conditions at low altitudes either do not exist or can be eliminated. The safety rules that must be observed for oxygen are as follows:

1. Never permit oil, grease, or other readily combustible substances to come in contact with oxygen cylinders, valves, regulators, gages, and fittings. Contamination with hydrogen, oils, or grease may result in a serious fire or explosion.
2. Never lubricate oxygen valves, regulators, gages, or fittings with oil or other flammable substances.
3. Do not handle oxygen cylinders or apparatus with oily hands or gloves.
4. Never use oxygen from a cylinder without reducing the pressure through a suitable regulator.
5. Use only approved oxygen regulators, hose, and other appliances.
6. Never attempt to use oxygen cylinders for other than oxygen service.
7. Never use oxygen as a substitute for compressed air. It is dangerous to use oxygen for pneumatic tools, for starting diesel engines, for guilding up pressure in oil reservoirs, for paint spraying, for blowing out pipelines, and similar purposes for which compressed air is normally used.
8. Never use compressed oxygen or any other compressed gas for cooling the body or for blowing dust from the clothing.

Liquid Oxygen

Many naval aircraft are currently equipped with liquid oxygen systems.

Aircraft liquid oxygen systems are similar to gaseous systems except that the several cylinders of gaseous oxygen are replaced by a single liquid oxygen container known as a converter.

The liquid oxygen converter is located in the oxygen system compartment. In some instances the oxygen compartment may be located on the left-hand side of the aircraft and in others it is on the right-hand side. In either case, location is such that the filler valve can be reached by a man standing on the ground or wing. The latest systems are designed so that the converter may be removed from the aircraft for filling at a remotely located filling station.

There are a number of additional safety precautions to be observed when handling liquid oxygen. Some of these parallel the safety precautions outlined for the handling of gaseous oxygen; however, they are worth repeating to help prevent accidents. Any possible danger that may occur is based on the general characteristics of liquid oxygen. First, the rate of combustion of most materials can be greatly increased by liquid oxygen; second, contact with liquid oxygen (-297° F) can cause severe frost-bite and damage to equipment vulnerable to freezing conditions; and third, liquid oxygen, if confined, will eventually evaporate and build up a tremendous pressure which could result in the rupture of the tank in which it is stored. Because of these possibilities, there are a number of safety precautions which must be observed.

The ADR, if he is a plane captain, is responsible for the observance of all safety precautions even though he is not actually performing the work of servicing the aircraft. The following safety precautions should be observed while recharging an oxygen system on the flight line, or the flight deck, if aboard ship. Only qualified personnel or personnel being trained and under the direct supervision of a qualified person, should be allowed to operate liquid or gaseous oxygen trailers or storage tanks. The plane captain should insure that the following conditions exist while the system is being serviced:

1. The aircraft is in an open area.
2. The aircraft is not being fueled.
3. The aircraft is electrically grounded.
4. The APU or starting units are not connected to, or operating in the vicinity of the aircraft.
5. A CO_2 fire extinguisher is immediately available.
6. All personnel are kept clear of the overboard vent.
7. The deck under and in the immediate vicinity of the overboard vent is free from grease, oil, or any combustible material.

In addition to the above mentioned items, never park a liquid oxygen trailer near gas trucks, oil bowsers, or foreign material receptacles. While servicing the aircraft, always wear the proper protective clothing. Do not permit liquid oxygen to flow onto any part of the body or clothing, or into pockets, cuffs, gloves, shoes, and the like, where it might be trapped and cause severe freezing. In the event that liquid oxygen is spilled on clothing, the clothing should be removed immediately.

Compressed Air

The safety precautions with regard to compressed air are much the same as for the other compressed gases. Of course, compressed air is neither poisonous nor flammable, but at the same time you should not become careless in handling it. Compressed air tanks, lines, and fittings have exploded, injuring men and property. Literally thousands of careless men have blown dust or harmful specks into their eyes by the negligent handling of compressed air outlets. Because compressed air seems so safe in comparison with the other gases, do not let overconfidence lead to your own or someone else's injury.

Although landing gear shock strut servicing is the responsibility of personnel of the AMH rating, the ADR plane captain must be familiar with the hazards involved during the deflation and inflation procedure.

Shock struts are first filled with hydraulic fluid while in the compressed condition, then extended the proper amount by inflating with highpressure air or nitrogen. Some struts require nitrogen, others use dry air. An instruction plate, attached to the strut, lists the type of gas to be used.

Before deflating a shock strut, always make certain that all personnel, workstands, jacks, and other obstacles are clear of the aircraft. On some aircraft, the wingtip drops several feet when one of the shock struts is deflated.

Always deflate the strut by gradually loosening the hex head swivel nut in the high-pressure air valve. When loosening the swivel nut, make sure the larger hex body nut is either lockwired in place or held tight with a wrench. If the hex body nut is loosened before the pressure has been released, serious injury may result.

Make certain the shock strut compresses as the pressure is released. In some cases it may be necessary to rock the aircraft to insure complete compressing of the strut.

To inflate a strut, always use a regulated high-pressure source of dry air or nitrogen. Never use any type of bottled gas, other than air or nitrogen.

The proper amount of extension is always given on the instruction plate attached to the strut.

AIRCRAFT SERVICING

Servicing of aircraft includes replenishing of the fuel, oil, hydraulic fluid, and other consumable materials. The general procedures for these servicing operations, along with the related safety precautions, are discussed in the following paragraphs.

NOTE: All aircraft servicing should be performed in accordance with the applicable set of Maintenance Requirements Cards.

FUEL REPLENISHMENT

Aircraft reciprocating engine fuels are presently classified into types and grades in the following manner:

U.S. Military Grades	U.S. Commercial Grades	Color	NATO Symbol
80/87	80/87	Red	F-12
91/96	91/98	Blue	F-15
100/130	100/130	Green	F-18
115/145	115/145	Purple	F-22

Current plans provide for the use of a single grade of AvGas (aviation gasoline) on a worldwide basis in the event of hostilities. At present, 115/145 AvGas is the primary fuel for reciprocating engine aircraft both overseas and within the continental United States.

Many aircraft operate satisfactorily on all approved fuel grades. Whenever a lower grade of AvGas is used, the applicable flight manual must be referred to so that power settings may be revised, commensurate with the grade of fuel in use. When going to a higher grade fuel, the published power settings or curves must be adhered to for all flight conditions. NOTE: When changing from one type of authorized fuel to another, it is not necessary to drain the aircraft fuel system before adding the new fuel. The engine operating limits for operating on mixed grades of AvGas must be the limits for the lowest grade of fuel in the tanks.

There are two methods of refueling aircraft–gravity and pressure fueling. These, along with the related safety precautions, are discussed in the following paragraphs.

Refueling Safety Precautions

Aviation gasoline is a highly volatile liquid which gives off a vapor. This aircraft fuel vapor is heavier than air and will settle to the ground, accumulating in dangerous amounts in depressions, troughs, or pits; and when combined with air in the proper proportions, forms an explosive mixture.

The ignition of vapor from aircraft fuel may occur from static sparks, sparks from tools, hot exhaust pipes, lighted cigarettes, electrical devices, and similar sources. A violent explosion followed by fire will result if liquid gasoline is present.

All existing fire precautions must be adhered to during the fueling process. Smoking is not permitted in the aircraft during fueling. Also, no smoking or naked lights (such as are produced by oil lanterns, candles, matches, exposed electric switches, sliprings or commutators, a dynamo or motor, any spark-producing electrical equipment, or any burning material) are permitted within 100 feet of an aircraft being refueled, or of fuel storage tanks. No lights other than approved explosion-proof lights are permitted within 50 feet of these operations, and no light of any sort may be placed where it may come in contact with spilled fuel. Warning signs should be posted as a precautionary measure.

All accidental spillage of aircraft fuels or other combustible liquids must be immediately removed by washing, covered with a foam blanket to prevent ignition, or neutralized by other means. The proper fire authorities must be notified any time a large amount of aviation fuel is spilled.

Aircraft fuel tanks must be filled, purged, or have an inert gas (such as CO_2) over the gas in the tanks before storing aircraft in hangars, since this leaves no space for explosive vapors to form.

Nonspark tools must be used when working on any part of a system or unit designed for storing or handling combustible liquids.

The use of leaky tanks or fuel lines is not permitted. Repairs must be made on discovery, with due regard to the hazard involved. The fuel must be strained if there is the slightest chance that water may be present. Most fueling trucks and underground storage systems have filter/separators which automatically filter water out of the gasoline before delivering it to the aircraft tank. These filter/separators should be checked daily for dirt and water. This system serves the same purpose as the sediment bulb or tank in an automobile gasoline system.

Aircraft should be fueled in a safe place. Do not fuel or defuel an aircraft in a hangar or other enclosed space except in case of emergency. Aircraft should be free from fire hazards, have engine switches off, and chocks placed under the wheels prior to fueling or defueling.

CAUTION: Guard against breathing hydrocarbon (fuel) vapors as they may cause sickness or may even be fatal. Do not let fumes accumulate—use adequate ventilating measures. Also, avoid getting fuel on clothes, skin, or in the eyes, because of the high lead content. Fuel-saturated clothing should be removed as soon as possible, and the parts of the body exposed to fuel washed thoroughly with soap and water. Wearing clothing saturated with fuel creates a dangerous fire hazard, and painful blisters may be caused by direct contact with fuel in the same manner as fire burns. When fuel has entered the eyes, medical attention should be obtained immediately.

When an aircraft is to be fueled by a truck, it should not be located in the vicinity of possible sources of ignition such as grinding, drilling, or welding operations. When practicable, a minimum of 50 feet from other aircraft or structures and 75 feet from any operating radar set should be maintained. Consideration must be given to the direction of the wind so that fuel vapors will not be carried toward a source of ignition.

The tank truck should be driven to a point as distant from the aircraft as the length of the hose permits, and preferably to the windward (upward) side of the aircraft. It must be parked parallel to or heading away from the wing, or in such a position that it may be driven away quickly in the event of fire. As soon as the fueling operation has been completed, the truck should be removed from the aircraft's vicinity. The truck manhole covers should be kept closed, except when a tank is actually being loaded, or when pumping fuel at 25° F or below, because at such temperatures vent valves may be inoperative.

NOTE: The operation of fuel trucks at many air stations is performed by civilian crews. Even though the ADR may not be called on to operate or drive fuel trucks, he must be thoroughly familiar with the entire procedure to insure safety of the fueling operation, in which he will be involved frequently.

Refueling crews usually include a minimum of three men. One person stands by with the firefighting equipment; another stays with the truck; and the third man handles the fuel hose at the aircraft and fills the tanks. A member of the crew makes sure that both the aircraft and the truck are properly grounded to prevent sparks from static electricity. A check should be made to see that all radio equipment and unnecessary electrical switches are turned off. Outside electrical power should not be connected to the aircraft unless it is necessary to operate the equipment involved with refueling. Care should be taken to identify the aviation fuel before beginning the refueling operation. Refueling trucks have the type fuel contained in the tanks painted across the side of the tank in black letters. An ADR who is involved with servicing aircraft should become familiar with the various grades of fuel and the aircraft's fuel requirements in order to insure that the appropriate fuel is always used.

Gravity Fueling

Gravity fueling is accomplished by grounding the nozzle (fig. 15-1), inserting the nozzle in the cell filler neck, and filling the tank to the bottom of the filler neck port.

The nozzle should always be grounded prior to being placed in the filler neck in order to prevent sparks caused by static electricity. The nozzle should be supported while in the filler neck to prevent damage to the filler neck and in the case of aircraft which use bladder type fuel cells (cells made from a type of rubberized nylon cloth) to prevent the possibility of damaging the cell with the end of the nozzle.

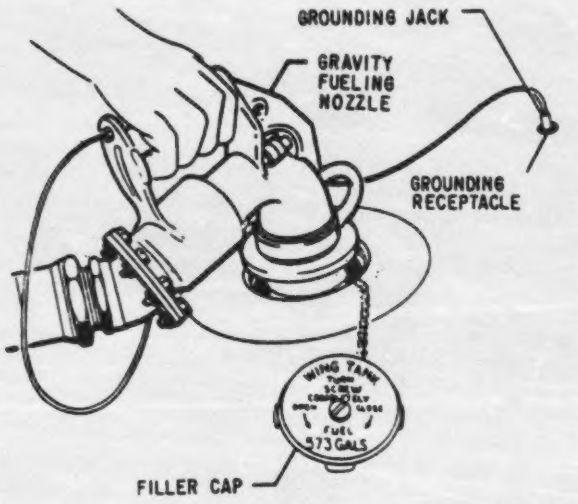

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Figure 15-1.–Gravity fueling.

When a tank is nearly full, the rate of gasoline flow should be reduced for topping off the tank. The tank should be slowly filled to the top without spillage.

Pressure Fueling

Most of the newer naval aircraft are refueled by the pressure fueling system. This is employed to enable faster "operational turn around" of the aircraft.

Pressure fueling is usually accomplished from a single point. Fuel from this point is supplied to the various wing and fuselage tanks. In some cases, the drop tanks and flight refueling package may also be refueled from this point.

The pressure fueling station on the aircraft is equipped with a pressure fueling and defueling receptacle and an electrical control panel. (see fig. 15-2) The pressure fueling receptacle is standard on all aircraft which use the pressure fueling method. The electrical panel and controls differ from one aircraft to another, depending upon the complexity of the fuel system. The more complex systems may require several switches and lights. The General Information and Servicing section of the applicable Maintenance Instructions Manual contains illustrations and instructions concerning the pressure fueling system.

The pressure nozzle shown in figure 15-2 is permanently attached to the refueler hose. The pressure nozzle is equipped with a ground wire which is used to drain off any static electricity which may have built up in the nozzle. However, once the nozzle is attached to the aircraft, it acts as its own ground.

As the connection is made, the pressure nozzle opens a spring-loaded valve within the inlet to the fuel tanks. Once the connection is made, there is no further need for grounding the other cells or tanks. Aircraft which employ the pressure fueling system are equipped with automatic equipment for shutting off the fuel flow when the tanks are full.

The following is a general procedure for pressure fueling an aircraft. Since the controls differ from one aircraft to another the applicable Maintenance Instructions Manual should always be checked prior to pressure fueling an aircraft.

1. Remove the pressure fueling receptacle safety cap by turning counterclockwise. Pull the pressure fueling nozzle dust cover up and to one side of the outer shell.
2. Ground the nozzle by inserting the grounding plug into its receptacle on the aircraft.
3. Lift the nozzle by its handles into position and engage the lower slot over the lower lug on the fueling receptacle. Tip the nozzle so that the upper slots engage the upper lugs. Press the nozzle in firmly so that all three nozzle lock keys are depressed. Lock the nozzle by rotating the lifting handles clockwise.
4. Set the refueling panel switches in the proper position and apply electrical power to the aircraft.
5. Position the vent monitors as necessary in accordance with the applicable Maintenance Instructions Manual. NOTE: The vent monitors are assigned to the various fuel system vents to insure that the aircraft's fuel cells are venting properly. Should the cells not vent properly, there is a possibility of rupturing the cell and even causing major structural damage.
6. With the nozzle locked in place, the opening handle is free to turn whenever fueling is to be started. To start fueling turn the handle to the FULL OPEN position. Rotating the opening handle more than 180 degrees opens the

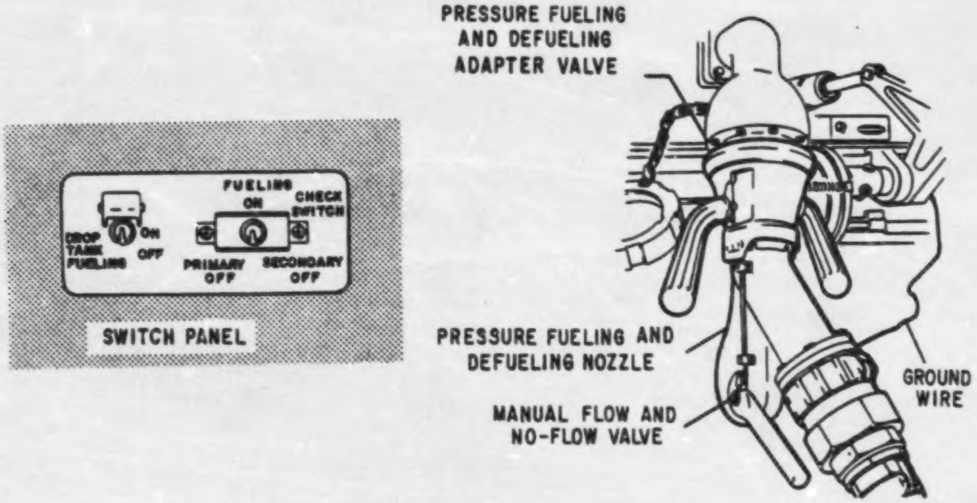

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Figure 15-2.–Pressure fueling.

poppet valve in the nozzle and locks it in the OPEN position. Position the appropriate switch on the fuel panel to the FUEL position. The fuel should shut off automatically when the cells are full.

CAUTION: During pressure fueling the fuel system should be inspected carefully for leakage. If any leaks are apparent, fueling should be stopped and corrective action should be taken.

7. When fueling is complete, the pressure fueling nozzle is removed by rotating the lifting handles counterclockwise until the nozzle is unlocked from the fueling receptacle. The dust cover should be pulled up over the nozzle face immediately and the safety cap replaced on the aircraft receptacle.

Every safety precaution must be taken to insure that no dirt or foreign matter enters the nozzle and that the nozzle nose is completely clean before it is connected to the aircraft. The dust cover must be kept on the nozzle at all times except when actually fueling an aircraft.

The pressure fueling nozzle can be damaged by careless handling. Guard against dropping the nozzle or allowing it to swing heavily against structures or equipment during handling. Never drag the nozzle on the deck.

Never force the operating action of the nozzle. If the unit does not couple freely or open or close readily, locate and correct the misalignment or mechanical jam.

Defueling

Defueling is necessary for various reasons such as fuel cell repairs, removal of external fuel tanks, and changing the fuel load.

Aircraft which utilize pressure fueling are normally defueled from the pressure fueling adapter. This allows the entire system to be defueled from a single point. Older aircraft have one or more defueling valves which are constructed so that the defueler hose may be clamped on. When defueling external fuel tanks, it may be necessary to insert the defueler hose in the filler port.

When defueling aircraft, always follow the instructions and safety precautions contained in the applicable Maintenance Instructions Manual.

OIL REPLENISHMENT

After the aircraft's fuel tanks are filled, the oil tanks are checked. These tanks should NOT be filled to capacity. Never fill an oil tank above its FULL mark. When oil becomes hot, it expands; at high altitudes it bubbles and expands. The extra space in the oil tank allows for expansion and prevents overflowing. Check the engine's oil requirements and no substitutions should be made for the type of oil used. When filling the tanks, be sure that rags or other debris do not get into the tanks. Foreign material in the oil may cause engine failure.

Lubricating oil itself is nonexplosive, very difficult to ignite in bulk, and not normally capable of spontaneous combustion. The vapor of the oil, however, is explosive when mixed with air in certain proportions. Vapors of many petroleum products are highly toxic when inhaled or ingested. It is therefore necessary that all precautions be observed when handling lubricating oil.

HYDRAULIC FLUID REPLENISHMENT

Aircraft hydraulic fluids are identified by their military specification number. Hydraulic fluid, MIL-0-5606, is now being used in the hydraulic systems of all naval aircraft. This fluid is also used in the shock struts, shimmy dampers, and brake systems of all aircraft. MIL-0-5606 hydraulic fluid is colored red, has a petroleum base, and comes in red, 1-gallon containers.

Servicing Hydraulic Systems

Older type aircraft hydraulic systems are serviced by checking the fluid level (on a sight gage which is usually located on the side of the reservoir) and filling to the prescribed level. Before adding fluid to this type reservoir, always check the reservoir instruction plate for the proper filling instructions. The instruction plate will be either attached to the reservoir or the aircraft structure near the filler opening of the reservoir. The instruction plate contains the following information:

Total capacity of the system.
Reservoir capacity.
Refill level.
Specification and color of fluid.
Correct position of all actuating cylinders during filling.
Any other instructions considered necessary during filling of the reservoir.

Fluid is usually added to this type reservoir by pouring directly from the can into the filler neck of the reservoir.

NOTE: After opening a can of hydraulic fluid the entire contents should be poured into an aircraft reservoir or into a portable fill stand immediately. This will eliminate the possibility of the fluid absorbing dust and grit from the air. Current instructions require that all empty hydraulic fluid containers be destroyed immediately and not used to store or handle any other fluid.

Newer type aircraft hydraulic reservoirs are filled from a fill stand similar to that shown in figure 15-3. The fill stand is connected to the aircraft hydraulic system at a quick disconnect which is provided for reservoir filling. Some aircraft systems provide for filling several reservoirs from a single point while others have provisions for filling each reservoir individually.

Most of these aircraft have a visible means (usually sight gages) for checking fluid level; however, some are equipped with lights which indicate fluid level.

Information concerning servicing of the hydraulic reservoirs of a particular type air-

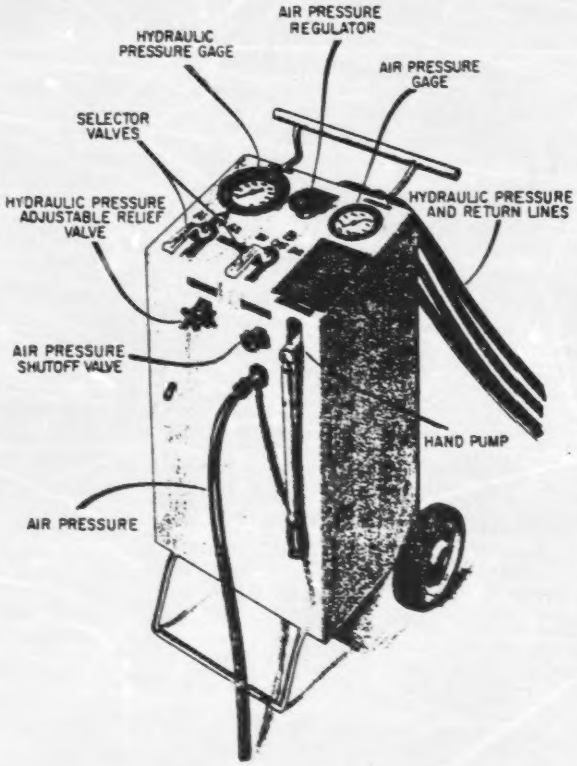
HYDRAULIC PRESSURE GAGE
AIR PRESSURE REGULATOR
AIR PRESSURE GAGE
SELECTOR VALVES
HYDRAULIC PRESSURE ADJUSTABLE RELIEF VALVE
HYDRAULIC PRESSURE AND RETURN LINES
AIR PRESSURE SHUTOFF VALVE
HAND PUMP
AIR PRESSURE

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Figure 15-3.–Hydraulic system fill stand.

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craft is contained in the applicable Maintenance Instructions Manual.

AIRCRAFT INSPECTIONS

Operating aircraft are subject to a variety of stresses, strains, vibrations, and detrimental environments. If not inspected regularly, the aircraft would soon become inoperable. Maintenance, such as correcting of discrepancies and timely lubricating, is performed in conjunction with inspections and enables the aircraft to be flown safely until the next inspection is due.

Types of inspections which are performed by activities responsible for the maintenance of naval aircraft are as follows:

1. Acceptance Inspections. A minimum acceptance inspection consists of an inventory of installed material and loose gear, configuration verification, functional test of appropriate emergency systems, and a thorough daily inspection. Accepting activities may elect to increase the depth of inspection if the aircraft conditions warrant.

2. Daily Inspection. Daily inspections are accomplished between the last flight of the day and the next scheduled flight, if no more than 72 hours elapse between the inspection and the next scheduled flight. If more than 72 hours elapse between the inspection and next flight, the inspection must be repeated. This inspection is basically a combination of requirements for checking equipment that requires a daily verification of satisfactory functioning, plus requirements that prescribe searching for and correction of relatively minor problems to prevent their progress to a state that would require major work to remedy. Other items which require inspection at intervals more frequent than prescribed for calendar inspections are also included on the daily inspection and are accomplished along with the daily inspection on the day they become due.

3. Preflight Inspection. The preflight inspection consists of checking the aircraft for flight readiness by performing visual examinations and operational tests to discover defects and maladjustments that, if not corrected, would cause accidents or aborted missions.

4. Postflight Inspection. The postflight inspection consists of maintenance requirements which are accomplished after each flight or ground operation of the aircraft. The postflight inspection is mainly a check for obvious defects (hydraulic, fuel, and oil leakage or structural damage) and the installation of the necessary safety locks and pins.

5. Calendar Inspections. These are limited overall examinations of the aircraft. Calendar inspections are conducted at the expiration of a specified number of calendar weeks. They consist of requirements that must be inspected at every calendar inspection plus requirements that are inspected at less frequent intervals. Most of the items that are to be inspected at less frequent intervals are divided evenly so that approximately half of the items are checked on the first (or ODD) calendar inspection and the remainder are checked on the second (or EVEN) calendar inspections. Subsequent calendar inspections repeat the same ODD-EVEN cycle.

6. Conditional Inspection. A conditional inspection is an inspection that depends upon occurrence of certain circumstances or conditions, or a maintenance action with a prescribed interval other than the preflight, postflight, daily, or calendar inspection cycle.

Periodic maintenance requirements for every model aircraft are promulgated by the Naval Air Systems Command. With every activity using the inspection criteria prescribed for their assigned aircraft models, it follows that any given aircraft model is subject to a standardized program of periodic maintenance wherever it is being operated.

Standardization of periodic maintenance procedures is accomplished by use of a Periodic Maintenance Requirements Manual (PMRM), various sets of Periodic Maintenance Requirements Cards (MRC's), sequence charts, and related forms and reports. These publications and forms and their use are described in the following paragraphs.

PERIODIC MAINTENANCE REQUIREMENTS MANUAL (PMRM)

The Periodic Maintenance Requirements Manual contains all the planned periodic maintenance requirements for the applicable aircraft model for its entire anticipated service life. The maintenance requirements contained in the manual are set forth in a manner to specify the equipments to be inspected or examined and the condition to be sought in each case. Since defects that are discovered during inspections result in unplanned maintenance, and this maintenance cannot be accurately predicted or planned for, this type of maintenance requirement is not included in the manual. Maintenance personnel must refer to the proper publications and directives for assembly, disassembly, check, test, and repair procedures.

Where conflict may exist between the information contained in the PMRM and other maintenance directives, the manual–with one exception–takes precedence. This exception is the information given on any Maintenance Requirements Card with a later date than the latest change date given in the PMRM. Although the information given in both of these directives should be identical, the cards can be, and usually are, changed before the manual.

MAINTENANCE REQUIREMENTS CARDS (MRC's)

The Maintenance Requirements Cards are the working documents for squadron inspections and preventive maintenance actions. These are 5 x 8 cards arranged by rating and work area to provide the most efficient sequence of accomplishment. Assembled into sets and numbered in sequence, the cards contain pertinent information required by each maintenance man to complete each task. Data for each task includes a description; the time required to perform the task; the power tools, equipment, and material requirements; and detailed information on such items as adjustments, pressures, and torque values. Also included, when necessary, is a diagram of the area in which the work is to be accomplished.

Individual sets of MRC's are prepared for preflight, postflight, daily, and calendar inspections. For aircraft models having odd and even calendar intervals, the calendar MRC set is further divided into three groups–calendar, odd calendar, and even calendar. The calendar group contains requirements that must be checked at every calendar inspection, while the other two groups are used alternately with the calendar MRC's. Therefore, at each calendar inspection, two, and only two, of the foregoing groups in the calendar set are used.

The work plan, or order of performing the requirements, specified on the Maintenance Requirements Cards is prearranged in two manners. The preflight, postflight, and daily work is performed item by item in sequential order arranged on consecutively numbered cards. The calendar inspection work is controlled by the order of arrangement of the items on the MRC's and, in addition, employs a sequence chart for scheduling of the MRC's. The calendar MRC's are not necessarily scheduled in numerical card number sequence.

NOTE: No part of any scheduled maintenance is certified (signed off) on the Maintenance Requirements Cards. Therefore, the MRC's may be used as many times as their condition permits.

SEQUENCE CONTROL CHARTS

Calendar Sequence Control Charts (SCC's) are used as a guide for the preparation of the actual calendar maintenance work schedule and a means of controlling the assignment of work and personnel. These charts indicate what MRC's are to be compiled with, the number and specialty of the personnel required, the times during which the separate jobs are scheduled for accomplishment, and the electric and hydraulic power conditions ("power on" or "power off") required during the work.

The SCC's are planned so as to effectively integrate all periodic maintenance work in a manner which will reduce the total out-of-service time required for the complete periodic maintenance job. The SCC's may consist of one, two, or three sheets according to the requirements of the aircraft model. Generally, small aircraft not requiring engine removal during calendar inspection will have only one chart containing both airframe and engine requirements to be accomplished on each calendar inspection. If engine removal is required for accomplishment of the calendar inspection, an engine SCC is provided for use by the work center performing the engine inspection.

Three charts are provided for aircraft models having inspection requirements divided between odd and even calendar intervals and requiring engine removal for inspection.

Calendar Sequence Control Charts have no application to the preflight, postflight, daily, or progressive aircraft rework requirements.

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A plastic cover is placed over the chart when in use to facilitate marking of progress by the supervisor. The chart and the plastic cover are therefore reusable for as long as their condition warrants.

A portable workstand is used by the Calendar Maintenance Supervisor to provide a local work control center for the accomplishment of calendar maintenance. This stand consists of four stowable legs, a deck tiedown assembly, plastic chart holder, and a partitioned carrying case for MRC control and storage. A center storage section is provided for reference maintenance manuals. This stand, with the Sequence Control Charts, becomes the control center for the supervisor of the entire calendar inspection.

MAINTENANCE RECORD FORMS

Maintenance record forms are used to enable aircraft maintenance activities to schedule daily maintenance requirements, assign work in a preplanned manner, establish responsibility for work performed, and record component replacement and discrepancies discovered, as well as the corrective action taken. The following paragraphs describe the forms provided.

Daily Schedule Maintenance Planning Record

The Daily Schedule Maintenance Planning Record is used to plan and project the daily scheduled maintenance requirements for each individual aircraft between calendar periodic maintenance periods. It aids in assuring that required maintenance is scheduled on time and enables supervisory personnel to plan workloads accordingly. The form provides a number of spaces for each day in which to enter MRC numbers that require compliance on a basis other than every day (7 days, 14 days, conditional, etc.) and provides a means for writing in all other scheduled maintenance due during the calendar maintenance period designated for the aircraft. This form is filled out to cover the calendar period. This is accomplished while the aircraft is undergoing calendar periodic maintenance so that all scheduled maintenance for the subsequent operating period is known at the time the aircraft is returned to an operational status.

Preflight/Daily/In-Flight Maintenance Record

This record form is used in conjunction with the Daily Schedule Maintenance Planning Record to enable scheduled work to be assigned in a preplanned manner between calendar inspections. This form controls and assigns responsibility for preflight, postflight, and daily scheduled maintenance including the special and conditional work that may be required. These forms can be prepared daily or made up in numbers sufficient to cover a desired period of time. Local conditions provide the best indication of the method to be employed.

INSPECTION PROCEDURES

Calendar

Under the direction of the activity maintenance officer, Maintenance Control holds a planning conference several days in advance of the calendar inspection due date with representatives of Quality Assurance, the production divisions, the designated Calendar Maintenance Supervisor (CMS), and key members of the forthcoming calendar inspection team.

The purpose of the conference is to prepare the sequence control chart by adding on any existing additional requirements. Representative items added on at this time are recent local or command maintenance items, discrepancies, component replacements, change incorporations, and other like items which either cannot be anticipated or cannot be programed into all inspections on a fixed basis.

After the preinspection planning conference, the marked up SCC is forwarded to Quality Assurance whose personnel certify that local inspection procedures are incorporated and that necessary MRC's publications, and required maintenance personnel are available and alerted. The marked copy of the chart is then forwarded to the CMS who prepares the necessary forms required for the inspection.

To initiate the calendar inspection, the supervisor issues MRC's, in the sequence prescribed by the Sequence Chart, to personnel

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of each rating who make up the inspection crew. A single copy Maintenance Action Form (MAF) is issued to check crew personnel each time a segment of the card set is issued for accomplishment. When the inspection or servicing requirements specified on the cards are fulfilled, the MAF is completed by the person accomplishing the work or his crew leader and returned with the MRC's to the supervisor.

The supervisor marks the SCC to indicate the cards issued. Return of completed cards to the supervisor is also reflected on the chart. Even though the workstand provides a physical accounting, by separation, of the completed and uncompleted MRC's, the supervisor double-checks the return of each MRC by noting it on the chart. A mark should exist on the chart for each completed card, each card not in possession of the supervisor, and each card that could not be completed due to parts on order or unscheduled maintenance.

Accomplishment and completion of each issue MRC are the responsibility of the appropriate specialist of the inspection crew. Each card must be completed by the specialist and returned to the supervisor. Uncompleted MRC's are returned to the supervisor and the Maintenance Action Form must contain entries listing the number of cards and items completed, and a notation in detail of which items were not completed and why.

Control of the status and scheduling of the calendar inspection is the responsibility of the supervisor. It is essential that all discrepancies discovered clear through him. The supervisor issues the necessary Maintenance Action Forms to the appropriate work centers for the correction of discrepancies which cannot be corrected by the calendar maintenance crew.

Preflight, Postflight, and Daily

A set of Preflight, Postflight, and Daily Maintenance Requirements Cards is maintained in the line shack for each aircraft assigned. Prior to each flight, the plane captain and other applicable personnel are issued the preflight cards appropriate to their rating or job. As each item is completed, it is signed off on a Preflight/Daily/In-Flight Maintenance Record which is returned to the line shack along with the cards when the preflight inspection is completed.

The Preflight/Daily/In-Flight Maintenance Record should be filled in completely prior to returning it to the line shack. Inasmuch as several preflight inspections may be in process at the same time, it becomes especially important that the BUNO and MODEX (or side number) spaces be accurately filled in. In some cases these records may be locally preprinted with the necessary basic information (applicable card number and rating), and the person performing the work needs only to complete the necessary spaces in longhand.

Daily inspections are accomplished in the same manner as are the preflight inspections. The accomplishment of the items on the daily inspection cards is also reported on the Preflight/Daily/In-Flight Maintenance Record. The daily inspection card sets contain the minimum daily, special, and conditional maintenance requirements for the applicable aircraft. Those card requirements that are to be performed on every daily inspection are titled "Daily." Those card requirements that are titled "Special" and "Conditional" are performed at the appropriate period which is determined by elapsed flight hours, aircraft status, mission requirements, or other consideration. Whenever these special or conditional items are to be included in the daily inspection, the appropriate cards are issued to the persons concerned as part of the daily card set.

GROUND SUPPORT EQUIPMENT MAINTENANCE REQUIREMENTS CARDS

The Aviation Machinist's Mate may be required to perform periodic inspections on the aircraft maintenance support equipment peculiar to his rating. To facilitate the inspection and repair of aircraft maintenance support equipment, sets of Daily and Periodic Maintenance Requirements Cards have been developed for each major type of equipment. By following the sequence set forth in the card sets, the minimum inspection requirements of the equipment are satisfied.

The Daily Maintenance Requirements Cards set forth the requirements for daily inspections, which are performed by the activity using the equipment.

The Periodic Maintenance Requirements Cards delineate the requirements for calendar inspections, which are performed by personnel of the Aviation Support Euipment Technician (AS) rating.

RECIPROCATING ENGINE OPERATION

One of the duties of the ADR is the turning up and checking of reciprocating engines. The basic turnup procedure varies with different types of aircraft, but by checking the applicable technical manual for the specific aircraft, the ADR should be able to turn up and check the aircraft with limited supervision.

Actual engine performance is an extremely important part of the inspection procedure. The factors involved in the inspection of engines during engine turnup and shutdown are similar for various types of aircraft. In the following discussion the S-2D aircraft is used as a typical aircraft.

Before an aircraft engine is turned up, certain precautions must be taken. Make sure that chocks are in place at the wheels of the aircraft, and that the aircraft is tied down, if required by local policy. Remove such things as control surface battens, control locks, and pitot tube covers. Check to insure that the ignition switch is in the OFF position, and that the mixture control is the IDLE CUTOFF position. Check the ramp around the aircraft to insure that the area is clear of debris. Check the fuel and oil tanks for proper grade and quantity. The man at the controls must be fully qualified in the type of aircraft which he is to turn up. Make sure that a fireguard is posted with the required firefighting equipment, and that the fireguard and the man at the controls clearly understand the signals to be used by them.

Starting

Before starting the engines, check to see that all personnel are safely clear of the propellers and that the wheels are chocked. Make certain that standby firefighting equipment is manned.

To start the engines, proceed as follows:

1. Starter switch–ON.

NOTE: If there is unusually high friction, have the spark plugs removed from the lower cylinders and drain all liquid, as the presence of any quantity of liquid in a combustion chamber is likely to cause serious damage. Never turn the propeller opposite to engine rotation, as this may force liquid into the intake pipes, from where it is apt to be drawn back into the cylinder when the engine is started.

Turn the switch to left for left engine and to right for right engine. Hold the switch to turn each propeller through 4 revolutions (12 blades).

2. Left and right auxiliary fuel pump switches–ON.
3. Master ignition switch–ON (PUSH IN).
4. Throttle–CRACK OPEN FOR APPROXIMATELY 1,200 PRM.
5. Starter switch–ON AND HOLD.
6. Ignition switch–BOTH.

After propeller has turned 2 revolutions, set ignition switch to BOTH.

NOTE: Continuous cranking should not exceed 30 seconds. If the engine does not start, release the starter switch and allow the starter to cool.

7. Primer switch–ON.

Move primer switch to ON intermittently until engine fires; then hold ON while gradually opening throttle to clear up exhaust and obtain smooth operation.

NOTE: Excessive throttle opening and intermittent priming after the engine has fired are the principal causes of backfiring during starting. Gradual opening of the throttle while priming continuously will reduce the initial overrich mixture to a smooth running, best power mixture as the engine picks up speed. An overrich mixture is sluggish but will not backfire.

8. Mixture control–RICH.

Watching tachometer, move mixture control to RICH after engine is operating smoothly on primer. Release primer switch as soon as a drop in rpm indicates that engine is receiving additional fuel from carburetor.

If the oil pressure indicator does not show pressure within 30 seconds, stop the engine and investigate.

9. Throttle–ADJUST.

Adjust throttle after transfer from primer to carburetor has been accomplished–800 to 1,000 rpm.

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NOTE: Start the other engine by repeating steps 5 through 9, above.

10. Generator and transformer-rectifier warning lights–NOT GLOWING.

These warning lights should not be glowing.

11. External power supplies–DISCONNECT.

Instruct ground personnel to disconnect external power.

If an engine fire develops during the starting procedure, continue cranking to start the engine and blow out the fire. If the engine does not start and the ground crew signals to cut the engine, proceed as follows:

1. Mixture control–IDLE CUTOFF.
2. Emergency fuel and oil shutoff switch–CLOSE.
3. Emergency hydraulic oil shutoff switch–CLOSE.
4. Cowl flaps switch–CLOSE.
5. Auxiliary fuel pump switch–OFF.
6. Fuel selector valve control–OFF.
7. Individual ignition switch–OFF.

NOTE: Do not attempt a restart until the reason for the fire has been determined and the cause corrected.

Turnup Checks

After the engine has been started, it is necessary to ascertain if the various engine components and systems are operating normally. In order to do this, the ADR should perform the following procedures before performing the remaining turnup checks:

1. Throttle–ADJUST.

Run engines at 1,100 to 1,300 rpm.

NOTE: Spark plugs will foul rapidly at low idle rpm if the idle mixture is not adjusted properly.

2. Oil pressure indicators–CHECK.

After 1 minute, 40-psi oil pressure should be indicated (15-psi minimum at idle).

3. Oil temperature indicators–CHECK.

Warm up at 1,100 to 1,300 prm until oil temperature reaches 40° to 95° C.

NOTE: An excessive rise in oil pressure when throttles are advanced indicates that further warmup is necessary.

4. Left and right oil cooler door switches–OPEN.

When oil reaches satisfactory operating temperatures, open oil cooler doors as required. Return switch to OFF to stop operation of doors at desired setting.

5. Fire detector test switch–TEST.

Set the test switch to TEST momentarily. The fire warning lights should light.

ELECTRICAL SYSTEM CHECK–Check the electrical system as follows:

1. Generator and transformer-rectifier warning lights–CHECK.

Check lights with engines idling at 650 rpm to see that they are NOT GLOWING.

NOTE: Both a-c and d-c power must be continuously supplied in the aircraft from the time of engine starting in order to provide stable power to the electronic equipment installed.

2. Throttles–ADJUST.

Adjust throttles for idling speed of 800 to 1,000 rpm.

3. Voltmeter–115 ± 2.5 VOLTS.

4. Frequency meter–400 ± 4 CYCLES.

NOTE: Persistent wild fluctuation of the frequency meter indicates failure of the constant speed drive.

5. Left and right generator control switches–OFF-RESET.

All electrical power in aircraft should be lost.

6. Left generator control switch–ON.

Left generator should be reenergized and power should be restored to aircraft instruments and warning lights. The NO R GEN and LOSS OF TR warning lights should glow.

7. Right generator control switch–ON.

All power should be restored to the aircraft and ALL warning lights should go out.

NOTE: If generators fail to reenergize, battery failure is indicated.

8. Communication and electronic equipment–CHECK OPERATION.

9. Pilot's and copilot's electrically driven instruments–CHECK.

Check for proper functioning of instruments.

HYDRAULIC SYSTEM CHECK.–Check the hydraulic system as follows:

1. Left and right hydraulic system pressure gages–1,400 to 1,500 psi.

2. Landing gear position indicator–CHECK.

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Check landing gear position indicator to determine that gear is down and locked.

FUEL SYSTEM CHECK.—Check the fuel system as follows:

1. Fuel flow—CHECK.

Check fuel flow from left tank to right engine and from right tank to left engine for 2 minutes with rpm over 1,200. Return system to normal, left tank to left engine and right tank to right engine.

2. Fuel quantity and fual quantity gage test switch—LEFT MOMENTARILY, THEN RIGHT. Applicable gage pointer should move toward lower end of dial. Pointer should then return to its original position when test switch is released.

3. Warning lights test switch—HOLD TO TEST (momentarily). Fuel low level warning lights—GLOWING.

CARBURETOR ALTERNATE AIR CHECK.—Check the carburetor alternate air as follows:

1. Throttles—SET TO 1,200 to 1,400 RPM.
2. Carburetor air switch—ALTERNATE.

Check for rise in carburetor air temperature within approximately 30 seconds.

3. Carburetor air switch—DIRECT.

INSTRUMENT CHECK.—With the propellers set for FULL INCREASE and the engines operating at 1,500 rpm, perform the instrument check as follows:

1. Oil temperature—CHECK.
   Grade 1100 oil—85° to 95°C.
   Grade 1065 oil—65° to 75°C.
2. Oil pressures—65 to 75 psi.
3. Fuel pressures—23 ± 2 psi.

Check with the auxiliary fuel pumps OFF and then ON.

4. Cylinder head temperatures—100° TO 245°C.
5. Carburetor air temperatures—5° to 38°C.
6. Constant speed drive oil temperatures—80° to 120°C.

PROPELLER CHECK.—Perform the propeller check as follows:

1. Parking brake—LOCKED.
2. Propeller rpm control levers—FULL INCREASE (LOW PITCH).
3. Throttles—SET FOR 1,500 RPM.
4. Operate propeller rpm control levers through complete range from FULL INCREASE to FULL DECREASE (high pitch) three to four times; then return to INCREASE. Engine rpm should change due to propeller pitch change. This procedure will also expel any air in the propeller control oil lines.

AUTOMATIC PROPELLER FEATHERING CHECK.—Perform the automatic propeller feathering check as follows:

1. Propeller feathering button lights (both)—GLOWING.
2. Automatic feathering arming switch—ARMED. Armed light—GLOWING.
3. Throttle—SET FOR 1,200 RPM (approximately). Torque pressure—BELOW 125 PSI.

Left automatic propeller feathering test switch—HOLD IN TEST POSITION.

After approximately 1 1/2 seconds, engine rpm should decrease as feathering starts.

NOTE: Check that manual feathering button moves to the depressed position.

4. Test switch—RELEASE TO OFF (after a drop of approximately 200 rpm). Unfeather manually.
5. Arming switch—RECYCLE TO OFF AND ARMED.
6. Repeat steps 3 through 5 for right propeller.
7. Advance both throttles approximately 200 rpm so that torque pressure is at least 150 psi, and check that holding left and right test switches in TEST position for at least 1 1/2 seconds has no effect on feathering of propellers.

NOTE: In the event the start of propeller feathering results in the loss of a generator, replacement of the associated supervisory panel is indicated. Electrical power from the live engine is restored by operating the associated generator control switch to the OFF-RESET position and then back to ON, or by operating the a-c bus tie switch momentarily to ON.

FIELD BAROMETRIC MAP POWER CHECK—Perform the field barometric MAP power check as follows: With propellers at FULL INCREASE, set throttles to that manifold pressure which equals current field barometric pressure. At standard sea level conditions rpm should read 2,250 ±50 rpm. On a cold day, check rpm will be less than 2,250; at higher altitudes (reduced barometric pressure) check rpm is higher.

IGNITION CHECK.—Perform the ignition check as follows: With propellers at FULL

INCREASE, set throttles so that manifold pressures equal field barometric pressure. Clear engines in NORMAL mixture for 15 seconds; then return to RICH. Move right engine ignition switch from BOTH to R and back to BOTH, then from BOTH to L and back to BOTH. Allow rpm to stabilize on BOTH before switching. Normal dropoff in either L or R position is 50 to 75 rpm; maximum allowable is 100 rpm. Repeat foregoing procedure for left engine.

IDLE MIXTURE CHECK.–Check closed-throttle idle mixture by manually leaning mixture until a noticeable decrease in rpm is obtained. There should be a slight rise of 10 to 20 rpm just prior to the noticeable decrease in rpm, and no change in manifold pressure, during this process if the mixture adjusting screw has been properly set for a BEST POWER mixture. With the throttle still set to the IDLE position, hold the primer switch to the applicable position (LEFT for left engine, RIGHT for right engine) until a noticeable decrease in rpm is obtained. There should be no increase in rpm or decrease in manifold pressure during this process if the mixture adjusting screw has been properly set for a BEST POWER mixture.

NOTE: Idling for a few minutes with a manually leaned mixture is better than operating at high power to burn out carbon deposits.

FULL POWER CHECK.–In the event a full power check is required, the procedure is listed below:

1. Advance right throttle to obtain 2,750 to 2,800 rpm, manifold pressure 53 to 56.5 in. Hg. Decrease rpm immediately to idle (650 rpm).
2. Repeat this procedure for the left engine.
3. The Flight Manual should be checked for maximum limits and operational conditions to be observed.

NOTE: A check should be made to insure that the aircraft is properly chocked and that the high power tiedown of the aircraft has been completed. A last minute check should be made to be sure that there is no loose gear or debris near or behind the aircraft that would be affected by the propeller blast.

Stopping Engines

In stopping the engines, perform the following steps:

1. Main wheels–CHOCKED.
2. Propeller automatic feathering arming switch–OFF.
3. Propeller rpm controls–FULL INCREASE.
4. Mixture controls–IDLE CUTOFF.
5. Individual engine switches–OFF (after engines stop).
6. Master ignition switch–OFF.
7. Throttles–CLOSED (fully).
8. Fuel selector valve controls–OFF.
9. All electrical switches–OFF.
10. All hatches and doors–CLOSED.

After the operational runup has been completed, the plane captain must insure that the Preflight/Daily/Inflight Maintenance Record is initialed and signed.